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ABSTRACT

This manual contains 17 instructional units (sequenced to correspond to parallel chapters in a student's manual) focusing on upgrading the design of wastewater plant facilities and serving as a reference source for establishing criteria for upgrading wastewater treatment plants. The manual also furnishes information for modifying plant design to compensate for current organic and hydraulic overloads and/or to meet more stringent future treatment requirements, emphasizing the importance of modifying existing plants and designing new plant facilities to accommodate operations, maintenance, and other routine plant functions. Each instructional unit contains title page, lesson plan, objectives, index to visual aids, and presentation guide. Topics considered include: field experience--designing for operability; maximizing plant operations feedback; plans and specifications reviews; general design considerations; unit process designs (headworks, primary sedimentation, aeration basins, secondary sedimentation, disinfection, effluent discharge, sludge treatment, other biological processes, and other factors--safety, energy conservation and emergencies); systems approach to unit process selection; equipment selection and placement for operability (flexibility and maintainability); and "an operator speaks to the design engineer." (Author/JN)

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ED219249

A COURSE ON OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT PLANT DESIGN

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INSTRUCTOR'S MANUAL

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Prepared for:

U.S. Environmental Protection Agency
Municipal Operations Branch
Washington, D.C. 20460

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NOTICE

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FOREWORD

The main purposes of this manual are to examine seventeen areas of consideration for upgrading the design of wastewater plant facilities, and to serve as a source of reference for establishing criteria for upgrading wastewater treatment plants. The manual also furnishes information for modifying plant design to compensate for current organic and hydraulic overloads and/or to meet more stringent future treatment requirements.

This manual emphasizes the importance of modifying existing plants and designing new plant facilities to accommodate operations, maintenance and other routine plant functions.

The numerous types and sizes of treatment plants which require periodic upgrading necessitate a thorough understanding of the fundamentals of the various types of existing treatment units and associated unit operational procedures.

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GENERAL INFORMATION FOR INSTRUCTORS

COURSE GOALS

This course is designed for practicing consulting, Design Engineers; plans and specifications reviewers/approvers; public officials; and state or other agency training personnel.

The content of this course stresses the importance of incorporating operational control, flexibility and maintainability into the design of wastewater treatment facilities. The content focuses on practical, field-proven approaches to improving performance through good design. A course problem involving a visit to a local operating treatment plant is suggested to assist participants in applying the course concepts and methodologies to actual plant situations.

The course presentation package consists of Instructor's Manual, Student Manual and Visual Aids Package.

INSTRUCTOR'S MANUAL

The Instructor's Manual to a course on "Operational Considerations in Wastewater Treatment Plant Designs" contains seventeen units of instruction. Each unit is sequenced and corresponds to parallel chapters in the Student Manual.

The Instructor's Manual is designed to cover the same content as the Student Manual with additional instructional information inserted in appropriate locations. Each instructional unit contains the following information:

Title Page
Instructor Lesson Plan
Unit Objectives
Index to Visual Aids
Instructor's Presentation Guide

Instructor materials serve as a guide for the presenter to follow. They do not propose the only way to present the material, but do represent the manner in which the units were prepared.

If the presenter believes that he can present the material more effectively by rearranging the sequence or adding different media, that is his/her perogative. The key to the presentation is the objectives list. Whatever the presentation does, it should enable students to meet the objectives listed for the unit.

Instructor Lesson Plan

The Instructor Lesson Plan provides information to familiarize the instructor with the overall structure of the lesson. Included is the "Overall Instructional Goal" - the skills that will be developed in the student because of the presentation;

the Method of Instruction: - the type of presentation, e.g. lecture, film, workshop or site visit; Lesson Length; Instructional Resources - e.g. Student Manual print material, slides, viewgraphs or films; and General Plan of Instruction - an overview of the way the content is arranged and presented to the students.

In the field test of these materials, a field trip to a plant was conducted. Students were provided an opportunity to discuss information received during the visit. The presenter is encouraged to develop a means of evaluating the attainment of specific unit objectives by his/her students if she/he desires, though no guidelines are provided in the instructor materials.

Unit Objectives

The Unit Objectives are the capabilities that the student can demonstrate as a result of the presentation.

Index To Visual Aids

The Index of Visual Aids lists the slides and viewgraphs for the unit that are in the Visual Aids Package. They are indentified by slide number and/or figure and table number in the Student Manual along with their caption.

Instructor's Presentation Guide

In the "Guide" instructional aids are aligned with unit topics and where useful, major points within topics.

A description of the slides or viewgraphs in the Visual Aids Package and their identification numbers are indicated. There is a viewgraph for every figure and table in the Student Manual except for the appendices. With the "Guide" the instructor can align slides and view graphs with the presentation and student manual materials.

The presenter should note that the slides or graphics provided may not be as good as examples from the presenter's files. Certainly, slides of your own will be more meaningful to you, and consequently your anecdotes will be more interesting to students. Thus, you should feel free to substitute or add slides from your own file if you think they are better examples of the concept presented.

The content and sequencing of the information in the "Guide" corresponds to the way the content in each unit of the Student Manual is arranged.

STUDENT MANUAL

Presenters should be sure to go over the student manual materials in their unit. The Student Manual contains the following information:

Manual Goals

The purpose of the Student Manual is to provide technical guidance for persons involved in the design and/or evaluation of wastewater treatment plant as a design consulting engineer or a state or federal regulatory agent.

This manual furnishes information of primary importanct to persons involved in designing wastewater treatment plants which provide maximum operation control, flexibility and maintainability. The most commonly recognized limitations which affect plant operation are identified and described along with correctional measures provided in the manual and workshop.

It is assumed that the manual user has an engineering background and has a general familiarity with wastewater treatment plant design.

Manual Format

In order for this manual to be an effective tool in wastewater treatment plant design, one should be familiar with the organization of the manual. The manual includes:

Table of Contents - Quick location of specific content areas.

Unit Objectives - Performances students should be capable of at the end of each section. The instructor should be aware of the objectives and focus the presentation on their attainment.

Unit Text and Figures - The body of the presentation.

Unit Resources - References and sources for additional information.

VISUAL AID PACKAGE

For each unit that has visual media there is an Index of Visual Aids with identifying numbers and captions, a set of slides for the unit, and a set of viewgraphs of the figures and tables in the Student Manual. The viewgraph number is the same as the figure or table number. Listed in the Instructor's Presentation Guide are the slide number for which there is also a viewgraph of the figure or table. Since most of the figures are of wastewater treatment plant design plans the instructor may prefer to use the brighter and clearer viewgraphs rather than the slides of the figures.

The instructor is encouraged to thoroughly familiarize himself with the projected slide and viewgraph visual aids. Many of the slides are panoramic in nature and the described features are not always immediately apparent.

INTRODUCTION

UNIT 1

OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT
PLANT DESIGN - UNIT 1

INSTRUCTOR LESSON PLAN

Unit Title: Introduction

Instructional Goal: To introduce the instructors and to familiarize the student with the course goals and Student Manual format.

Method of Instruction: Lecture/Staff introduction.

Lesson Length: 1 hour

Instructional Resources:

Student Manual print materials
Instructors
Unit Objectives

General Plan of Instruction:

- Introduce the instructing staff
- Describe:
  - Background
  - Course Goals
  - Student Manual Goals
  - Student Manual Format

INTRODUCTION - UNIT 1

COURSE OBJECTIVES

At the conclusion of the presentation of the course the participant shall be able to:

- Identify wastewater treatment plant designs which avoid operational problems associated with meeting effluent criteria.
- Maximize plant design operations feedback.
- Prepare reports, plans and specifications for reviews.
- Design unit processes with optimum operability, flexibility and maintainability.
- Incorporate a unit selection process using a systems approach.
- Select and place equipment for operability, flexibility and maintainability.

INTRODUCTION - UNIT 1

INDEX TO VISUAL AIDS
Figure/Slide

(none)

Instructors Presentation Guide

Unit of Instruction 1
Introduction

Lesson Outline	Illustration/Key Points
I. Background	
Ancient water and sewerage systems	Primary function of early systems was the disposal of surface waters.
Wastewater treatment commenced in latter half of the 19th centruy.	The activated sludge system has been in use since 1914.
Difficulty of maintaining plants to meet effluent criteria.	Design effort must be given to "how and when" maintenance.
The primary function of designing and building a WWT plant is to produce a treated effluent of of desired quality.	The Design Engineer must commit his resources to meet the requirements to supply a suitable facility.
The Design Engineer and Operator must work together.	The Design Engineer must formulate goals and objectives into the design.
II. Course Goals	
This course is designed for practicing consulting, design engineers; plans and specifications reviewers/approvers; public agency officials; and state and other agencies.	
Content of this course stresses designing for operability, flexibility and maintainability.	Content focuses on practical, field proven approaches to improving performance through good design.
III. Manual Goals	
The purpose of the manual is to provide technical guidance for persons designing or evaluating WWT plants.	

Lesson Outline	Illustration/Key Points
The manual furnishes information of primary importance to designing for operability, flexibility and maintainability. It is assumed the manual user has an engineering background and general familiarity with WWT plants.	
IV. Manual Format Organization of the manual:	
Table of contents	Quick location of specific content areas.
Unit Objectives	Specifications to be expected from the information presented.
Unit Text and Figures	The body of the presentation.
Unit Resources	References and sources for additional information.

FIELD EXPERIENCE: DESIGNING FOR OPERABILITY

UNIT 2

FIELD EXPERIENCE: DESIGNING FOR OPERABILITY - UNIT 2

INSTRUCTOR LESSON PLAN

Unit Title: Field experience: Designing for Operability

Instructional Goal: To provide the student with a general awareness of operating field experiences and their effect on the designing of facilities for operability.

Method of Instruction: Lecture/Slides

Lesson Length: 2 hours

Instructional Resources:

Student Manual print material
Slides
Unit Objectives

General Plan of Instruction:

- Review general operational considerations in wastewater treatment plant design.
- Discuss operational design features as shown by field experience

FIELD EXPERIENCE: DESIGNING FOR OPERABILITY - UNIT 2

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Identify wastewater treatment plant designs which avoid operational problems associated with meeting effluent criteria.
- Recognize and provide design features to deal with flow changes.
- Recognize the effect of combined sewers on the operation of wastewater treatment plants.
- Plan a wastewater treatment plant design so the degree of complexity is compatible with the skills of the operator.
    - Identify a wastewater treatment plant where the degree of automation is compatible with operational and maintenance skills of the staff.
    - Identify a wastewater treatment plant which incorporates only that automation equipment which is cost, labor and energy efficient.
- Provide a plant layout that:
    - Is suitable to the geographic location.
    - Minimizes movement during operation and maintenance procedures.
    - Enhances access to equipment.
    - Minimizes environmental effects to the neighborhood.
    - Is desigend to operate in the climate of the area.
    - Provides for minimal manual labor in material handling.
    - Provides hydraulic arrangement, distributes flow equally and provides flexibility for outages.
    - Provides operator with flow measurement devices and controls for process operation
    - Is capable of handling flow under all conditions.

FIELD EXPERIENCE: DESIGNING FOR OPERABILITY - UNIT 2

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	Good access to all units	-1C
	Good road access to grit chambers	-1E
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	Flow diversion after sharp bend	-27
	Provision of head loss to each channel	-28
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	DO probe encrusted with debris	-40
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	High freeboard in a trickler to inhibit freezing problems; shroud plate over aerator to prevent freezing	-67
	RAS return should be visible	-26
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	Good arrangement - no hard floor	-64
	Poor access to valve controller	-70
	Switch is too high	-69
	Difficult to change lightbulbs	-85
	Poor installation of valve	-74
	Good arrangement in pipe gallery	-77
	Pipe runs should have sufficient headroom	-9
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Tables

(none)

Instructors Presentation Guide

Unit of Instruction 2:
Field Experiences - Designing For Operability

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Success or failure of a WWTP to meet its discharge criteria depends on both process design and operability.	
1. Must provide operators with flexibility and the means to attain peak plant operating performance.	
2. Designer should be acquainted with plant operation and the situational restraints of the operators themselves.	
B. National Pollutant Discharge Elimination System sets forth effluent limitations to be met by a treatment facility.	
1. Describes frequency of samples. 2. Defines types of samples. 3. Defines analytical methods. 4. Must submit reports on a monthly basis.	
C. EPA current definition of 85% BOD removal as a monthly average in the worst month of the year.	
1. Given facilities are designed to average 90% BOD removal or better in order to guarantee that no month goes below 85%.	
D. If influent BOD is greater than 200 miligrams per liter the plant is required to meet 30/30 BOD and suspended solids requirements.	
1. If a plant has influent of 300 miligram per liter BOD then 270 miligrams or 90% must be removed to get to 30 miligrams BOD. Such a plant would have to be designed to remove 95% of BOD in order to assure that a worst month average of	

Lesson Outline	Illustrations/Key Points
90% removal (in order to get 30 miligrams BOD or less) was met. E. Compliance with NPDES regulations requires a more conservative design approach than was used in the past. 1. Role of operator in achieving design performance is more critical. 2. Operator has needs inherent in obtaining effluent objectives. These needs must be met by the designer. II. Influent Flow and Load Variations A. In order to produce an effluent of a desired quality, influent flow and load variations must be allowed for in facility design. B. Historically, <u>average</u> flows and loads have been used in facility design. 1. Some regulatory criteria still address only <u>average</u> values. 2. Design criteria established for <u>average</u> conditions may be unable to satisfy abnormal flow and load requirements. C. The use of an 800 gallon per day per square foot surface overflow rate in a secondary settling tank is a classic example of misuse of <u>average</u> data. 1. This criteria was developed in large plants which did not experience peak flows much greater than 1.5 times average inflow. D. If the 800 gallon/sq. ft./day criteria is applied in a plant which receives peak flows of three to five times the average flow then solids washout and deterioration of effluent quality can occur. 1. The operator may be blamed for poor effluent quality which is in reality the responsibility of the facility designer.	

Lesson Outline	Illustrations/Key Points
E. Because many treatment plants will start up at flows and loads as low as 10-20% of design capacities it is essential that initial conditions be considered critically by the design engineer.	
1. Many times metering devices are overdesigned for initial flows resulting in a lack of or misrepresentation of flow data to an operator.	
2. Lack of consideration of initial conditions may result in oversizing pumps, blowers, chlorinators, and chemical feeders.	
a. In order for the plant to be efficient and economical at low flows these pieces of equipment must be sized appropriately.	
3. Wide disparities between initial flows and operating flows will necessitate the use of equipment that can be changed out or altered 'in place' when the needs arise.	
4. The effect of recycled loads from sludge processing operations is a major concern in the sizing of critical treatment plant components.	Slide 2-32: Quantity of recycle can have a tremendous effect on the loading to a plant.
5. Digester supernatent, thickener overflow, and heat-treated sludge liquor returns must be assessed in the design process.	Slide 2-33: In the beaker on the left is the raw sewage to the plant. The plant influent is on the right after sewage has been combined with recycle.
a. Allowances in facility design must be made for the presence of return flows to BOD, suspended solids and nutrients if a plant is to function properly.	
III. Industrial Waste Associated Problems	
A. The design of a facility must acknowledge the presence of industrial wastes.	
1. Need to know quality and quantity of waste.	
a. Many firms provide enormous information based on optimum operation of their facility. The optimum may be the exception rather than the rule.	

Lesson Outline	Illustrations/Key Points
b. If possible, obtain independent data to corroborate information provided by industry. c. Determine possible fluctuations in flows and loadings to the maximum extent possible. d. Determine the effects of toxic chemicals contained in the waste on biological systems. e. Acquire a detailed knowledge of industrial operations, products, and effluent quality, quantity, and timing since each may have a profound influence on the required types and sequences of treatment processes. f. The rate at which industrial waste is produced and released to a system can adversely affect biological treatment. Rate is a major design consideration. 1. If an industry generates 1000 lbs. of BOD in an eight-hour day the rate of generation during the production period is 3000 lbs. per day. 2. Tanks, flow systems, aerators and other equipment must be sized to handle the effective 3000 lb/day flow rather than the actual 8-hour flow of 1000 lbs. BOD. 3. A cost effective solution to the peak discharge treatment dillema is to require the industry to discharge during treatment system low flow periods or to install equalization equipment (basin or other) in order to decrease the effective rate of discharge. g. Physical and chemical characteristics of an industrial waste must be considered when designing a wastewater treatment facility.	

Lesson Outline	Illustrations/Key Points
1. Sludge handling and aerobic digestion may be adversely affected by the presence of large quantities of oil and grease.	
2. Sludge permeated with grease and oil is difficult to dewater and incinerate.	
3. Some industrial waste may become very odiferous when thermally conditioned.	
4. Some industrial wastes may contain debris which interfere with pumping and mixing of sludge.	
5. Some wastes may not lend themselves to particular types of dewatering equipment.	
6. Some industrial wastes may require more than the normal horsepower needed in activated sludge systems due to the effect of the waste on oxygen transfer coefficients.	
h. Contributions from all important industrial users must be considered if the best possible treatment system is to be designed and made operable.	
i. Insufficient design which results from a lack of or incompleteness of baseline information may force an operator to spend most of his workday on normal plant operations thus neglecting required maintenance and other responsibilities.	
IV. Siting Considerations	
A. Facility layout can contribute to maintenance and operation of a plant, as well as providing an aesthetic impact.	
B. Wastewater treatment plants should be buffered from the surrounding community.	Slide 1-A: Clustering of all unit processes makes maintenance and operation simpler. Redundancy of size of multiple units simplifies maintenance and operation.
1. Use of grass in all non-paved areas will enhance facility appearance.	

Lesson Outline	Illustrations/Key Points
2. Trees and shrubbery are not advised for use on facility grounds due to potential obstruction of views, and proclivity to drop debris into open tanks.	Slide 1-C: Access to all portion of each unit process is desirable Rectangular construction saves space and permits easy expansion using common wall construction.
C. It is desirable to cluster unit processes around a centrally located operations building.	
D. Frequent maintenance is promoted if distance between units is small.	Slide 1-E: Provide road access to processes, such as grit chambers, that require trucks to remove materials. Note: Tree in background provide buffer between plant and surrounding populace.
E. Rectangular tanks occupy minimal area, and simplify expansion through the use of common wall construction.	
F. Designers should provide operators with easy access across tanks to assist in servicing all portions of the basins.	
G. Redundancy in size of multiple units of a single process will help simplify maintenance and operation.	Slide 1-F: Grass around unit processes is aesthetically pleasing, and easier to maintain than trees or shrubs.
H. Designer should visit existing facilities to acquire operator input.	
V. Flow Into the Facility	
A. All instream processes such as bar screens and comminutors should allow the following: 1. Isolation of components, 2. Draining capabilities, and 3. Easy access for routine servicing.	Slide 2-72: Comminutor should be designed with large channels for easy access.
B. Flow diversions in channels should be preceded by a straight channel to reduce losses and to insure equal flow distribution.	Slide 2-27: Flow diversion occurs after sharp bend in the channel. This may result in unequal diversion of flow into the separate channels.
C. When a single channel is provided for a battery of tanks operated in parallel there should be sufficient head loss provided at the entrance of each tank to assure equal distribution among the tanks.	Slide-28: Sufficient head loss should be provided at the entrance to multiple tanks off a common channel to insure equal distribtuion of flow to each tank.

Lesson Outline	Illustrations/Key Points
VI. Aeration Basins	
A. Concentration of dissolved oxygen in aeration basins may be used as a feedback control to throttle the blowers.	Slide 2-38: DO in aeration basin used to decrease or increase throttling on blowers. Probes require daily maintenance to keep them free of debris.
1. DO probes must be serviced on a daily basis to keep them accurate	Slide 2-40: DO probe encrusted with debris. Slides 2-66, 2-67: High freeboards freezing problems (1) aeration basin, (2) trickling filters. Slide 2-65: Shroud plate over aerator to prevent freezing in winter.
B. Open tanks can be subject to freezing in winter. Hign freeboards on tanks and trickling filters will alleviate icing on the structures.	
1. Ice formation on aerators in activated sludge reactors can be prevented by using shroud plates.	
C. RAS must be controlled carefully to maintain adequate secondary treatment.	Slide 2-26: RAS discharge into aeration basin should be visible to the operator.
1. A visible discharge pipe for RAS into the reactors will aid operators in evaluating characteristics and quantity of return sludge.	
VII. Flow Control	
A. Design overflow weirs on 50 to 100 foot diameter tanks to be 1/4 to 1/3 of the radius distance offset in from the tank wall.	Slide 2-30, and 2-31: Overflow weirs on 50-100 foot diameter secondary sed tanks should be 1/4 to 1/3 of the radius in from the wall to minimize upflow velocitie into the weirs. For tanks larger than 100' in diameter, two concentric weirs should be designed.
1. Minimizes upflow velocities in the weirs.	
B. For tanks larger than 100' design two concentric weirs.	
C. When slide gates are used design slide and gate of the same material in order to prevent excessive wear and to forstall binding.	Slide 2-84: Aluminum slide gates in steel frame.
D. Locate slide gates between adjacent tanks to permit unit or dual operability	Slide 2-34: Slide gates permit the tanks to be operated as a unit, or singlely.
E. Flow control can be achieved by designing troughs that can be mechanically moved to permit more or less wastewater to overflow into the trough.	Slide 2-24: This trough can be mechanically moved to provide flexibility.

Lesson Outline	Illustrations/Key Points
VIII. Flow Measurement	
A. Parshal flumes are commonly used for flow measurements.	Slide 2-25: Sufficient upstream run should be provided for Parshall flume measurements so that flow is uniform before entering flume.
1. Should provide sufficient upstream run before the flume to insure flume accuracy.	
IX. Solids Handling	
A. Incorporate as many features as feasible to facilitate solids handling.	
B. Bar screen cleanouts should be accessible and provided with adequate utlity piping.	Slide 2-2: Bar screens remove course solids from the waste stream becoming unpleasant to service. Design bar screens to be cleared as easily and quickly as possible. Allow plenty of access, and appropriate utility piping.
C. Provide screen rooms and grit disposal areas with truck access if materials are to be hauled off site.	Slide 2-68: Provide adequate truck access to all process requiring movement of heavy materials.
1. If possible do not require operators to lift buckets filled with grit or screenings.	Slide 2-5: Operators should not be required to lift grit filled buckets such as these. Grit disposal facilities should be located on the same level as grit handling area to prevent excessive operator travel up and down stairs.
2. In small plants, wheel-mounted collection bins can be provided and are preferred.	Slide 2-8: Grit collector bins can be easily wheeled out to trucks for waste transport.
3. If direct operator handling is required disposal should be at the same elevation as collection to eliminate utilization of stairs.	
4. Overhead clamshell buckets can eliminate the need for submerged grit removal equipment while facilitating direct disposition into a truck.	
5. Conveyors can be used to transfer grit or screenings from several collection areas to a common dump point.	Slide 2-6: Conveyors used to transfer grit/screenings to a central dump point.
D. Use positive displacement pumps to handle scum collected on primary and secondary sedimentation basins.	Slide 2-18: Scum on secondary sed tanks should be removed and pumped to scum thickeners. Pumping eliminates need for trucking.
1. Scum can be pumped to thickeners and then combined with waste sludge for disposal.	
2. If scum pumping is not provided, scum must be disposed of separately.	

Lesson Outline	Illustrations/Key Points
3. Ultimate disposal of sludge often involves trucking of sludge to a landfill or land application site.	
a. Overhead piping of sludge to tank trucks will make loading of waste easier.	Slides 2-15, & 2-16: Access to waste sludge is greatly simplified at this European wastewater treatment facility.
X. Use of Automation	
A. Automation should be used judiciously since training of operators to service sophisticated control systems is difficult.	Slide 2-3: View of automated control facility.
B. Major criteria for automation include insurance of a more reliable and consistent efluent quality, or significant reduction of labor, chemical, energy, or other costs.	
B. All instrumention should be displayed prominantly with indicators that are quickly and easily read.	Slide 2-35: Operators should have ready access to instrumentation. All indicators should be easily read.
XI. Hazards Consideration	
A. Chlorine room requires special attention to details.	
1. Electrical hoists capable of handling cylinders of chlorine weighing up to one ton are recommended.	Slide 2-10: Note electric hoists for chlorine tank handling and indicating/recording scales o individual tanks.
2. Indicating and recording scales should be provided for each cylinder that is in use.	
3. Chlorine room should have access only to the outside through double doors equipped with panic bars.	Slide 2-11: Chlorine room should have access only from outside. Windows should not be opaque. Should be able to see in from outside.
a. Doors should include clear, untinted, strengthened windows for viewing chlorine room from the outside.	Slide 2-37: Poor access is shown Must go upstairs to get out of chlorine room. No safety equipment is near the door.
B. Fire and safety equipment should be very visible and within easy reach.	
XII. Cleanliness and Hygiene	
A. A major portion of wastewater treatment plant maintenance is devoted to cleaning.	

Lesson Outline	Illustrations/Key Points
B. Designers should include safeguards that reduce frequent cleaning needs including components that facilitate cleaning when cleaning becomes necessary.	
C. Dust should be prevented from accumulating on walls and other equipment.	Slide 2-59: Measures should be taken to suppress dust production and its release to the environment. Dust can create malfunctions in electrical equipment.
1. Wherever possible electrical instrumentation should be isolated from dust producing processes or environments.	
a. Incinerators	Slide 2-61: Electrical equipment too close to dust producing processes.
D. Sludge processing is a messy operation and should be isolated from sensitive equipment.	
E. All sludge handling components should be readily accessible for cleaning.	Slide 2-62: Locating control panels too close to sludge processing equipment (in this example, vacuum filters) can create splatter.
1. Sludge tank should be equipped with a suitably sized drain that enables operators to empty and clean the tank in one eight hour shift.	Slide 2-73: Note sludge spillage on sludge conveyor. This is a poor location for such a conveyor as it is not easily accessible for service.
F. Structures subject to solids deposition should be equipped with agitators to keep solids in suspension.	Slide 2-81: No drains in bottom of tank.
1. Channels. 2. Chlorine contact chambers.	Slide 2-76: Note good accessibility of sludge cleanout.
G. Floor drains should be located in all areas when water may accumulate on the floor.	
H. Personal hygiene is an important design consideration.	Slide 2-17: Solids deposition in chlorine contact chamber can be prevented by using air to continuously agitate the effluent. Vacuum removal of solids could also be provided.
1. Sinks, with hot water and soap should be located adjacent to laboratory facilities and where cleaning is a frequent part of maintenance.	Slide 2-56: Inadequate floor drainage.
2. Employees should be encouraged to wash themselves regularly after exposure to undesirable materials.	Slide 2-57: Floor drains to corner. Slide 2-58: Pumps should be provided with floor drains directly beneath. Slide 2-80: Water standing on floors due to lack of floor drains. Slide 2-54 & 2-55: Wash-up areas with hot water and soap should be provided where lab work is to be performed.

Lesson Outline	Illustrations/Key Points
XIII. Machinery Layout	
A. Machinery must often be moved for repair, thus cranes should be provided where heavy equipment is in place.	Slide 2-14: Crane access should be provided to all equipment. Example is a monorail to hoist a pump.
1. Example, influent pumps.	
B. Where the lifting power of a crane is not necessary, lifting inserts should be in sufficient quantity installed above the equipment.	Slide 2-43: Lifting inserts should be provided where cranes are not necessary or infeasible.
C. Care must be taken in design to insure that equipment or support beams do not interfere with the travel of cranes or monorails.	Slide 2-49: Example of 'juryrig' lumber support used where lifting inserts were not provided.
D. It is desirable to extend monorails to overhead door openings.	Slide 2-13: Example of monorail run to door permitting direct loading/unloading with no manual lifting.
1. Enables operators to move and load equipment onto trucks with a minimum of labor.	
E. Equipment galleries should be designed with sufficiently wide aisles to permit movement of dollies or fork lifts.	Slide 2-45: Gallery access with cranes for lifting pumps for maintenance is essential.
F. The location of equipment can have important effects on plant operation.	Slide 2-41 & 2-42: Insufficient clearance has been provided. Very difficult to remove the drum on this vaccum filter.
1. Large components should not be located in areas with low clearance or little maneuvering room.	
a. Example - Vacuum filters.	
2. Processes requiring regular servicing should be located away from hazardous areas such as stairwells or open machinery.	Slide 2-12: Equipment which is manually serviced, such as this chemical feeder, should not be located over open pits.
3. Blowers and centrifuges are noise makers and should be situated in rooms with low ceilings and sound absorbing floors and walls.	Slide 2-63: Blowers are often very noisy. Acoustical tile and other noise reduction measures are desirable.
4. Valve hand wheels must be located with good access. A hand wheel located behind pipes where the wheel can be reached only with extreme difficulty is frustrating and often untouched.	Slide 2-64: A good arrangement in a blower room. No hard tile floors, and low sound absorbing ceiling. Slide 2-70: Valve controller under pipe. Must provide better access.

Lesson Outline	Illustrations/Key Points
5. Electrical switches, lighting fixtures, and other non-process equipment should be located as required with every design effort made to make them highly accessible to the operator.	Slide 2-69: Switch is to high. Slide 2-85: Light bulbs can not be changed. Slide 2-74: Valve cannot stand up-right. Interferes with access
XIV Piping	
A. Pipe galleries can be difficult to service if not designed properly.	Slide 2-77: Good arrangement for the pipe gallery in this 100 MGD facility. All pipes accessible, visible, and out of the way. Plenty of room for walking and moving equipment.
1. All piping should be visible and readily accessible.	
2. Pipes should not be positioned one behind the other where an operator cannot reach them.	
3. Pipes should be labeled or color-coded.	
4. Pipes carrying caustic substances should be isolated or placed at lowest level relative to other piping so that leaked substances will not drop on other piping.	
5. Isles in galleries should be wide enough for passage of maintenance equipment.	
6. There should be sufficient clearance between the gallery floor and the piping to prevent head injuries.	Slide 2-9: Pipe galleries should be provided with sufficient headroom to prevent accidents. Slide 2-77: Insufficient clearance beneath pipes creates a safety hazard.
XV Walkways and Storage	
A. Walkways should be provided wherever operators are required to service equipment.	
1. Personnel should not have to walk across grass to reach a tank.	Slide 2-78: Too small a walkway.
2. Catwalks are useful for providng service for motors and machines located too high for operators to reach comfortably.	Slide 2-44: The bearing housing on these pumps was located 12' above the floor, thus, a catwalk was required to provide access.
B. Adequate storage for spare parts and chemicals is a necessity.	Slide 2-50: Storage rooms should have adequate space for all items to be stored therein.
1. Storage rooms should have both floor and shelf space in ample quantities.	

Lesson Outline	Illustrations/Key Points
2. Small parts should be shelved so that they do not clutter up the floor and become objects to trip the unwary.	Slide 2-51: No facilities for orderly storage of spare parts have been provided.
3. In order to conserve space, the walls should be designed as storage spaces for gas bottles. Straps or racks could be used.	Slide 2-52: No access to stored articles. Tanks are not strapped down or otherwise secured.

MAXIMIZING PLANT OPERATIONS FEEDBACK

UNIT 3

OPERATIONAL CONSIDERATIONS IN WASTEWATER
TREATMENT PLANT DESIGN - UNIT 3

INSTRUCTOR LESSON PLAN

Unit Title: Maximizing Plant Operations Feedback in the Design of Wastewater Treatment Plants

Instructional Goal: To encourage the student to develop an in-house system to record and use feedback from various sources in a formal design review system.

Method of Instruction: Lecture/Viewgraph

Lesson Length: 1 hour

Instructional Resources:

Student Manual print materials
Viewgraphs of figure and table
Unit Objectives

General Plan of Instruction:

Describe:

- Benefits of Feedback System
- Sources of Feedback
- Incorporating Feedback into plant design
- Using the Feedback System

MAXIMIZING PLANT OPERATIONS FEEDBACK IN THE DESIGN
OF WASTEWATER TREATMENT PLANTS - UNIT 3

OBJECTIVES

At the completion of this presentation the participant shall be able to:

- State the importance of obtaining feedback as a method to enhance quality of design.
- Identify sources of feedback which are available.
- Institute in-house feedback systems which are compatible with the size and nature of the firm.
- Establish formal in-house review system that maximizes the incorporation of the feedback into reports and designs as they are being produced.
- Produce plant designs that best represent the experience of the firm as a whole.

MAXIMIZING PLANT OPERATIONS FEEDBACK IN THE DESIGN
OF WASTEWATER TREATMENT PLANTS - UNIT 3

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Figures/Slides

Figure No.	Title	Slide No.
3.1	DESIGN REVIEW AND FEEDBACK SYSTEM	

Table

Table No.	Title	Slide No.
3.1	DESIGN REVIEW AND FEEDBACK SYSTEM: TYPES OF REVIEW DOCUMENTS AND REVIEW TEAMS	

Instructors Presentation Guide

Unit of Instruction 3
Maximizing Plant Operations Feedback
In The Design of Wastewater Treatment Plants

Lesson Outline	Illustration/Key Points
I. Importance of Feedback-Incorporating feedback from operating experience can improve the design of new WWT plants.	Feedback is a must to meet the newer more stringent NPDES standards.
Operator criticism of the Design Engineer.	Criticism can be overcome by gaining feedback from the operators and incorporating it into the design of new WWT plants.
The Design Engineer should make frequent visits to operating plants and plants under construction.	Undesirable and desirable features can be brought to light.
The purpose of a feedback system should be to identify desirable design features and to avoid undesirable features.	Many advances in the state of the art of plant design have grown out of suggestions from the feedback system.
A design team can always use inputs from others in the firm.	Methods to incorporate firm wide experience include a system of standard technical practice and the development of a useable information storage and retrieval system.
An effective plant operations feedback system results in a more effective plant design and enhances the design firms reputation.	The greatest testimony to a firm is a successfully operating WWT plant meeting effluent criteria.

Lesson Outline	Illustration/Key Points
II. Sources of Feedback	
The most important source of feedback is during WWT plant start-up.	The experience of start-up personnel should be passed on directly to the Design Engineer.
A common complaint is that the Operator never hears from the Design Engineer after plant acceptance.	It is to the Design Engineers benefit to ensure that the plant operator is well instructed.
Visits to plants designed by other firms are always useful.	The strong and weak points of other firms plants can be compared with those of the Design Engineers Firm.
Operator Forums can increase communication between the Design Engineer and Operator.	To provide effective feedback there must be constructive criticism and comment.
Valuable feedback can be obtained from resident representatives or Field Engineers.	As a resident representative, the Operator is in a position to identify undesirable design features which can be corrected during construction.
Informing Design Engineers of feedback from plant operations is by internal memoranda.	Once design, construction and startup personnel use memoranda a useful feedback system is established.
III. Incorporating feedback into designs. Firms must establish a policy to use a feedback system.	The key element to establishing a strong feedback system is the full support of the principals of the firm.
Access to a readily usable system of feedback data is essential to ensure that the data will be used.	This access can be through a filling system or a computer data system.
An important aspect of a feedback system is the selection of the design review team.	Table 3-1: Team composition is dependent upon the firms size and design phase.

Lesson Outline	Illustration/Key Points
The development of inhouse standards for specifications, design details, design policies and process criteria evolve over many years.	The ongoing process of establishing, reviewing and updating standards can incorporate feedback from plant operations; Attachment A is a method of documenting feedback.
The Firms management must establish milestones in the design process in which certain documents will be considered by the review team.	Figure 3.1 Design Review and Feedback System.

PLANS AND SPECIFICATIONS REVIEWS

UNIT 4

OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT PLANT DESIGN - UNIT 4

INSTRUCTOR LESSON PLAN

Unit Title: Plans and Specifications Reviews

Instructional Goal: To introduce the student to the content of reports that are to be submitted to reviewing agencies.

Method of Instruction: Lecture

Lesson Length: 1 hour

Instructional Resources:

Student Manual print materials
Unit Objectives

General Plan of Instruction:

- Introduce the student to several general plans and specification guides.
- Describe the content matter of an engineers report.
- Describe standards for plans and specifications.
- Describe standards for revisions, operation during construction, and erosion control plans.

PLANS AND SPECIFICATIONS REVIEWS - UNIT 4

OBJECTIVES

At the conclusion of the presentation of this unit the participant shall be able to apply various techniques when reviewing plans and specifications.

- He will be able to list the subject matters that will be required to be included in an Engineer's Report.
- He will be able to name several standard guides by which he may properly prepare the Engineer's Report for the plan and specification review process.
- He will be able to utilize the guides in his own environment.
- He will be able to prepare plant plans in formats that will facilitate the review process.
- He will be able to prepare plant specifications with a completeness that will benefit the builder in the construction of the best possible plant.
- He will be able to prepare revisions to approved plans using proper procedures.
- He will be able to specify procedures which will keep the existing plant operating during the construction period.
- He will be able to delineate control measures to minimize erosion during construction.

PLANS AND SPECIFICATIONS REVIEWS - UNIT 4

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Figure/Slide

(none)

Table

(none)

Instructors Presentation Guide

Unit of Instruction 4
Plans and Specification Review

Lesson Outline	Illustration/Key Points
I. Introduction	
The review process by which the plans and specifications will be evaluated.	Very early in the design process the Design Engineer should familiarize himself with regulations, policies, and standards pertaining to plans and specifications.
Guides for plans and specifications reviews.	"Guides for the Design of Wastewater Treatment Works of the New England Interstate Water Pollution Control Federation" "Ten State Standards"
Reports, plans and specifications should be submitted at least 60 days prior to the date for action.	Preliminary plans should be submitted for preliminary review.
II. Engineer's Report	
The purpose of the report is to present a clear description of the problem, alternative solutions, and their feasibility and environmental impacts.	The report should be written for public understanding and should be a summary of information needed by agencies to support the project.
A. General	
The report should include data on sewers, pumping stations and WWT Plants.	
* Brief description of project and need.	
* Classification of waters, permits and orders of state agencies.	

Lesson Outline	Illustration/Key Points
* Location	Describe geographic location of municipality and project.
* Topography	
* Population	Present, past and estimated future population involved in the proposed project.
* Water Supply	Discuss features of public health significance.
* Garbage Disposal	Present and potential future disposal of garbage.
* Field Survey Data	
* * Volume and strength of wastewater flow.	The Design Engineer shall confer with the reviewing agency to establish the scope of the data necessary.
* * Industrial wastes	List all establishments producing industrial wastes and give guantity, producing periods and character of industrial wastes.
* * Septic tank cleanings	
* * Soil investigations and core borings.	Discuss any unusual foundation conditions.
* * Infiltration inflow	Determine if the infiltration inflow can be most economically eliminated by repair of the sewer system or treated at the proposed plant.
* * Flooding	State what precautions against flooding are incorporated into the design.

Lesson Outline	Illustration/Key Points
B. Individual Systems	The report should assess the ability of abating existing conditions by construction of individual or small group disposal systems.
* Local soil conditions	Discuss the acceptability of local housing density, water supplies, soil and groundwater conditions to individual subsurface disposal.
* Reliability	Discuss the reliability of individual system where soil conditions are marginal.
* Municipal management	Discuss the feasibility of municipal management of septic disposal.
C. Land Treatment and Disposal	For projects receiving federal funds the report shall comply with EPA requirements.
* Summary survey of alternative sites	The most favorable sites should be studied in depth.
* Required land area and location	Define applicable positive or negative effects.
* Required pretreatment	Discuss industrial, seasonal and combined sewer factors.
* Agricultural benegits	Discuss positive and negative effects.
D. Innovative/Alternative Technology	Discuss their financial impact, reliability impact on growth and useful life.
* Examples of alternative systems	Reclaiming or reuse, land treatment, aquifer recharge, industrial reuse composting and energy recovery systems.

Lesson Outline	Illustrated/Key Points
* Examples of innovative systems	Developed systems not fully proven for the contemplated systems, greater recycling and conservation of water resources, improved efficiency and reliability, better management of toxics, greater beneficial use of sludge and other environmental benefits.
* Risks for desirable systems	Imprecise knowledge of their useful life, high dependancy on skilled operators or the requirement for substantial capital investment in the event of failure.
E. Water Conservation	Conservation may include public education, installation of water meters, low flow fixtures and pricing and regulatory actions.
* Feasible conservation measures	Estimate immediate and future wasteflow reductions and the cost implications.
F. Wastewater Treatment Works	
* Description of Contributory Areas	
* * The extent of the existing and proposed contributory areas to the proposed WWT plant.	
* * Areas of probable future sewer system contributory to the WWT plant.	
* * The location of the WWT plant and point of discharge with reference to the contributing sewer system.	
* * Present and proposed methods of treatment and disposal of septic tank cleanings.	
* Site	Indicate the proximity of residences or developed areas to any WWT plant.

Lesson Outline	Illustration/Key Points
* Type of process	Discuss the type of treatment processes studied and the reasons for choosing the recommended alternative.
* Description of existing plant	Discuss limitations of plant.
* Basis of design of the recommended alternative	
* * Design period	
* * Design population total	
* * Strength of wastewater	Allowance should be made for septic tank cleanings.
* * Total wastewater flows	
* * Initial and design flow rates	Peak instantaneous flows should be included.
* * Treatment units	
* * Receiving body of waters	If a stream, give the low flow determined with the method used by the reviewing agency.
G. Recommendation	
* Alternate plans	Discuss the several solutions and the reasons for selecting the one recommended.
* Sewer system	Describe the area and extent to which plans provide for future development.
* Wastewater treatment	Discuss the degree and type of treatment, reasons for adopting the proposed method, and adequacy for present and future needs.
* Financing: estimated cost of the system.	Give a summary of the anticipated means of financing the total project.
* Industrial wastes	Pertinent information should be provided on industrial wastes that should be excluded from the sewer system.

Lesson OUtline	Illustration/Key Points
III. Plans	
A. General	
The plans will show a suitable title, the scale, the north point, a date and the name of the engineer and his seal imprint.	
The plans shall be clear and legible.	
Detail plans shall consist of plan view, elevations, sections and supplementary views.	
B. Plans of Wastewater Treatment Plants	
* Location Plan	Sufficient topographic features shall be included to indicate its location with relation to streams and the point of discharge.
* General layout	
* * Topography of the site	
* * Size and location of plant structures	
* * Piping	
* * Hydraulic profiles	
* * Test borings and groundwater elevations	
* Detail plans	
* * Location, dimensions and elevations of all existing and proposed facilities	
* * Elevations of the receiving waters	
* * Type and size of pumps, blowers and motors	
* * Complete schematics for sludge and chemical piping	
* * Hydraulic flow in profile	
* * Adequate description of other features	
* * Laboratory facilities	

Lesson Outline	Illustration/Key Points
IV. Specifications The specifications shall include all construction information not shown on the plans.	Complete technical specifications will accompany the plans.
V. Revisions to Approved Plans	Any deviations from approved plans shall be approved in writing before such changes are made.
VI. Operation During Construction	Specifications shall contain a program for keeping existing plant units in operation during construction of plant additions.
VII. Errosion Control Plan	Measures to be taken to minimize erosion during the construction period should be delineated.

GENERAL DESIGN CONSIDERATIONS

UNIT 5

GENERAL DESIGN CONSIDERATIONS - UNIT 5

INSTRUCTOR LESSON PLAN

Unit Title: General Design Considerations

Instructional Goal: To develop in the student an overall awareness of general design considerations.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual Print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Show by examples general design considerations.

GENERAL DESIGN CONSIDERATIONS - UNIT 5

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- List four site factors to be considered in system location and layout.
- Explain why "type of treatment" is an important locational factor.
- List five factors which must be considered when designing for flexibility and reliability.
- Identify proper and improper design of materials and equipment handling facilities.
- Discuss from memory various maintenance considerations which have an effect on plant layout.
- Discuss the pros and cons of the use of automation at a given facility.

GENERAL DESIGN CONSIDERATIONS - UNIT 5

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	Photo of facility shown in Figure 5.4	-5
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(none)

Instructors Presentation Guide

Unit of Instruction 5:

General Design Considerations

Lesson Outline	Illustrations/Key Points
I. System Layout and Location	
A. Factors to be considered	
1. Site constraints such as availability of land, environmental restrictions.	
2. Type of urban growth in vicinity. Is best to locate away from areas of residential growth.	
3. Put buffer zones between plant and community if possible such as forest, railroad track, parks.	Slide 6-9: Buffer zones around plant site include railroad track, major highways, 2 rivers and an industrial park to the east. See Figure 5.1
4. Influence of the community such as need for odor controls.	
5. Type of treatment for example is sludge to be applied soil or hauled off.	
B. Type of Treatment	
1. Plant site must be appropriate for treatment methods chosen. Land treatment of treated effluent requires sufficient land area for application.	
2. The initial layout must be flexible to permit plant expansion.	Slide 6-1: Sunnyvale, Calif. wastewater treatment plant as originally constructed with sufficient property for future expansion of trickling filters on the west. See Figure 5.2
3. Desirable to minimize the number and complexity of unit processes in small plants, for example, sludge drying beds instead of mechanical dewatering equipment.	Slide 6-2: First expansion of additional anaerobic digester and primary sedimentation tanks with anticipated expansion to activate sludge on the west. See Figure 5.
C. Unit processes should be arranged to facilitate plant operation	Slide 6-3: Photo of Slide 6-2.
1. Use a centrally located operations building in small plants.	

Lesson Outline	Illustrations/Key Points
2. Use operations centers in large plants	Slide 6-4: Further expansion with larger digester and more primary sedimentation basins See Figure 5.4
D. Other Factors	
1. If plant is located in residential area, odors, mists, noise etc. must be considered	Slide 6-5: Photo of Slide 6-4.
2. Climatic conditions will influence the type of treatment processes, construction materials, housing of components, etc.	Slide 6-6: Latest expansion of plant with tertiary treatment facilities on west end of the property. There is still room left for future expansion as needed. See Figure 5.5
II. Reliability and Flexibility	
A. Need for Reliability and Flexibility	Slides 6-7 & 6-8: Photos of Slide 6-6.
1. Adapt treatment processes to changes in regulatory requirements.	
2. Facilitate maintenance and operation.	
3. Perform future expansions smoothly	
B. Selection and Arrangement of Unit Processes Should be based on Flexibility of Operation.	
1. Processes should permit maximum and minimum organic, solids and hydraulic loadings.	
2. Interconnecting piping and channels should permit equal distribution of wastewater flows over the entire range of flows to which the plant will be subjected.	
3. Hydraulic arrangement should permit removal of a unit from service without disrupting flow upstream or downstream.	Slide 6-60: A common effluent channel following a series of 12 primary sedimentation tanks. See Figure 5.6
a. There should be a common effluent channel from a battery of tanks.	
b. Hydraulic capacity of each unit process should be adequate to pass peak plant flow when an individual component of that process is taken out of service.	

Lesson Outline	Illustrations/Key Points
C. When several components of a unit process are necessary, the engineer should design in multiples of two. Components should be of equal size to provide good hydraulic distribution and maintenance redundancy.	Slide 6-18: Secondary sedimentation tanks of identical size arranged in pairs. See Figure 5.7 and Figure 5.9
D. Duplicate design of unit processes insures continued operation when equipment is taken out of service.	Slide 6-34: Duplicate bar screens in influent channels. See Figure 5.8
E. A storage basin capable of holding 2 to 3 days of flow is useful for emergencies.	Slide 6-17: Emergency storage basin in upper right background.
F. Equipment and materials handling	
1. Materials handling	
a. Sufficient storage near the site where chemicals are to be used should be provided.	
b. Truck access should be provided whereever these vehicles are needed to move materials.	Slide 6-51: Truck access to screen room.
2. Equipment handling	Slide 6-21: Crane system in pump building. See Figure 5.10
a. Cranes, hoists and lifting inserts should be readily available.	
b. Proper access design to all equipment should include wide galleries for the passage of forklifts and other machinery.	Slide 6-23: Crane system in screen room. See Figure 5.11
c. Alignment supports and easily disconnected electrical couples should be provided for all pump mechanisms particularly if the pumps are to be removed with cranes.	Slide 6-24: Picture of crane used for influent pumps. Slide 6-26: Cranes used in screen rooms.
d. Floors under disassembled equipment should be structurally reinforced and contain floor support.	Slide 6-22: Lifting inserts should be provided where cranes can't be used or aren't needed. See Fig.5.1 Slide 6-20: Wide gallery access in pump room.
G. Maintenance considerations	Slide 6-56: Centrifugal influent pumps.
1. Easy access to all equipment valves, gates and other operating devices should be provided.	

Lesson Outline	Illustrations/Key Points
2. Drain gates on basins should be recessed so tanks can be drained completely.	
3. Drainage system should permit a tank to be completely emptied and cleaned within one shift.	
4. Utility stations should be located throughout all tunnels and equipment areas.	Slide 6-134: Recessed drain gates in aeration basin. See Fig. 5.13
a. Wash-down water, service air, stram, or portable water should be within reach of 50 foot hoses.	Slide 6-27: Utility piping in screen room. See Fig. 5.14 Slide 6-47: Plan view of Slide 6-27. See Fig. 5.15
b. Electrical outlets should be readily available. Excessive use of extension cords or temporary wiring should be avoided.	
5. All galleries and utility tunnels should be drained, painted, illuminated and ventilated to provide a good working environment	Slide 6-98: Primary sedimentation gallery.
6. Color code lubrication points on all equipment	Slide 11-16: Galleries should be wide enough for equipment passage with piping up against the walls & ceiling to keep it accessible, but out of the way.
a. Label should identify parts to be lubricated and required types, frequencies, and amounts of lubricant.	
b. Recommended color code for lubrication frequency. Brown — Annually Red — Semi-Annually Blue — Monthly Green — Weekly White — Daily	
H. Automation	
1. Computer Control	
a. Should be hardwired field control of all processes to insure that plant can be manually run if computer goes down.	Slide 6-19: Hardwired local control as well as computer control. See Fig. 5.16
b. Computer control requires reliable sensing equipment that can be regularly serviced.	

Lesson Outline	Illustrations/Key Points
2. Degree of automation and instrumentation to be incorporated into a plant must be selected based on a practical understanding of plant operation. a. Automation should be kept to a minimum in small plants. b. Is desirable to equip automatic controls with a manual mode.	
I. During construction, attention should be given to installation of equipment. Alignment of pumps, motors and fans should be checked. Proper pump and valve packing should be checked. Instrumentation control and alarm system should be checked.	Slide 6-159: Slide gates and their storage inserts should be checked to assure that the gates can be removed and replaced.

UNIT PROCESS DESIGN - HEADWORKS

UNIT 6

UNIT PROCESS DESIGN - PRELIMINARY TREATMENT - UNIT 6

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Preliminary Treatment

Instructional Goal: To develop in the student an awareness of operational considerations in the design of preliminary treatment units.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 1/2 hours

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Show by examples operational features of preliminary treatment works.
- Review general theoretical considerations of grit collectors.

UNIT PROCESS DESIGN - PRELIMINARY TREATMENT - UNIT 6

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Define preliminary treatment.
- Identify factors which affect preliminary treatment facilities selection.
- Discuss at least four elements which should be included in the design of influent channels.
- Describe four types of screening devices, their utilization and important design considerations.
- List at least five important facts to be taken into consideration when designing screenings handling facilities.
- Explain four desirable attributes of comminutors which the designer can utilize.
- Explain the theoretical considertions underlying grit collector design.
- Identify Stokes' Law and describe its importance.
- Design a grit tank based on hypothetical needs.
- Discuss at least five important preliminary treatment "design hints" which have been presented.
- Write a description of grit dewatering.
- Design an efficient raw wastewater pump system that is relatively easy to operate and maintain.

UNIT PROCESS DESIGN - PRELIMINARY TREATMENT - UNIT 6

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Instructors Presentation Guide

Unit of Instruction 6:

Unit Process Design - Preliminary Treatment

Lesson Outline	Illustrations/Key Points
I. General Considerations	
A. Preliminary treatment generally consists of two processes.	
1. Screening	
a. Intercept coarse solids	Slide 6-23: Location of bar screens ahead of influent pumps. See Figure 6.1
b. Located ahead of the influent pumps	
2. Grit Removal	Slide 6-29: Location of grit tanks between influent pumps and primary sed. tanks. See Figure 6.2
a. Removal grit and other heavy materials	
b. Located between influent pumps and primary settling tanks.	
B. Process is subject to unattenuated fluctuations in diurinal and storm flows of wastewater	Slide 6-36: Plan view of preliminary treatment structural isolation. See Figure 6.3
1. Should structural isolated preliminary treatment to protect the rest of the plant from flooding. This should include all equipment and drains.	Slide 6-37: Section of same preliminary treatment system. See Figure 6.4
2. There should be no cross connections or electrical switchgear below maximum water level, should all pumps fail.	
3. For emergency operation and maintenance, the capacity to isolate the headworks from the rdw. influent should be a part of design.	
C. Ventilation	Slide 6-25: Schematic showing how exhaust from clean areas (blue arrows can be used to ventilate the screen room before being exhausted to scrubbers (red arrows) See Figure 6.5
1. Proper ventilation of screen room is necessary to prevent accumulation of noxious and dangerous gases. Ventilation air from clear areas can be used twice by recycling it through the screen room.	

Lesson Outline	Illustrations/Key Points
2. Exhaust pipes should be placed just above sewage conduits and the sewage pump suction level. Exhaust ventilation should be scrubbed to reduce odors.	Slide 6-27: Location of screen room exhaust pipes within walls above sewage conduits and sewage pumps. See Figure 6.6
D. Design screen room for maintenance	
1. Cranes and lifting inserts should be provided to remove and install bar screens, grinders, slide gates, etc.	Slide 6-49: Screen room showing wide aisle on left, access to slide gates to right of mechanically leaned bar screens and utility piping up against wall.
2. Truck access for debris hauling should be provided.	
3. Utility stations with air, water, steam connections and service sinks should be conveniently located.	Slide 6-50: Plan view showing truck access to screen room. See Figure 6.7
4. Equipment may be mounted on concrete parts to facilitate cleaning after flooding.	Slide 6-51: Photo of Slide 6-50.
II. Influent Channels	
A. Raw wastewater and return flow sampling.	
1. Both raw sewage and return flows determine plant efficiency and therefore both should be monitored	
2. For flexibility return flows and sewage should be capable of being monitored separately.	
3. Return flows from all unit processes should be combined and directed into the plant influent at a common point to permit metering and sampling of all return flows in one location.	Slide 6-30: Section showing return flow collection pump, sampling, pump and sampler, together with by-pass line to direct flow into influent channel if sampling meter fails. See Figure 6.8
4. Raw sewage must be sampled upstream of the recycled flow return points.	
5. Combined raw wastewater and return flows may be sampled in screen room or off the discharge side of the influent pumps.	Slide 6-31: A by-pass trough used for ph and conductivity measurements of raw sewage. The trough received sewage from influent pump and discharges it over a rectangular weir. Weir is lifted once per shift to remove debris. PH and conductivity probes were placed in the trough. The system is easy to monitor maintain and keep clean.
B. Flow division provides for flexibility as plant load increases and as flow fluctuates during wet and dry periods.	
1. Design should insure equal flow and solids distribution among all channels.	

Lesson Outline	Illustrations/Key Points
2. Agitation should be provided if natural distribution is in question.	Slide 6-61: Influent channel waste water kept agitated to prevent solids deposition.
3. Extra channels or channels capable of handling higher flows will provide the necessary flow capacity when the plant is expanded.	Slide 6-62: Shear fusers that provide air agitation for channel in Slide 6-61.
	Slide 6-32: Three bar screened channels with center acting as back up for higher flows. See Fig. 6.9
	Slide 6-33: Flow divisions into 4 influent channels from a single sewer allows for expansion of flow capacity. See Fig. 6.10
	Slide 6-34: Each of the 4 influent channels in Slide 6-33 has 2 bar screens, one acting as back-up. See Fig. 6.11
	Slide 6-35: Flow divisions from influent sewer to 3 then 6 influent channels. Each of the 6 channels. Each of the 6 channels has a bar screen and influent pump. See Fig. 6.12
4. Provide an ample straight run ahead of a splitting tee to insure that flow divides evenly. It is also good practice to provide a straight run ahead of metering equipment to ensure accurate flow measurements.	Slide 2-25: Good, straight run ahead of parshal flume.
III. Bar Screens and Comminutors	
A. Function of bar screens is to remove coarse material which could damage or adversely affect the operation of downstream equipment.	
B. Types of screening devices	Slide 1-1: Types of screening devices.
1. Bar screens: located ahead of influent pumps, designed to remove coarse solids by interception.	
2. Fine screens: disk or drums with stainless steel on non-ferrous wire mesh screen cloth with opening between 0.25 to 0.75 inches. Mesh size permits preliminary treatment.	

Lesson Outline	Illustrations/Key Points
3. Microscreens: designed to remove residual suspended solids from secondary effluents. Are rotating drum filters with fabric openings between 23 to 25 u. Typically remove 55% of residual solids from final effluent.	
4. Comminutors: provide instream reduction of particle size. These particles are then removed in grit chambers or primary sedimentation tanks.	
C. Design Considerations	Slide 1-2: Design considerations for screening devices.
1. Size of openings determines solids captured.	
a. Bar screens - 1.0 - 2.0" for hand cleaned, 0.6 - 3.0" for mechanically cleaned,	
b. Fine screens - 0.25 - 0.75"	
c. Microscreens - 23 - 25 U	
d. Comminutors - size governed by the size of the largest particle that can be allowed to pass.	
2. Hydraulic loading or velocity affects removal efficiency	
a. For coase screens, the removal efficency should be maximized, but care should be taken to avoid velocity reductions which cause sedimentation in the channels a 6" head loss is permissable through the screen.	
b. With fine screens, the hydraulic loading is governed by the solids in the feed, the desired efficiency and head loss considerations.	
D. Bar screens	
1. Require a great deal of maintenance and therefore must be disigned for this operation.	Slide 6-40: Screen room: Well lit crane access, wide aisles and utility piping.

Lesson Outline	Illustrations/Key Points
2. Operates should be able to isolate and drain the channel area around bar screens.	Slide 6-44: Solid lines indicate area where slide gates can be used to isolate channels around bar screens for maintenance. Note straight channel run ahead of bar screens to promote uniform velocity distribution across the screens. See Fig. 6.12
3. A straight channel ahead of the screen insures a good velocity distribution across the screen.	
4. Mechanical bar screens	
a. Should be heavy duty design with large sprockets and heavy weight chain.	
b. Back return/front clean type preferred	
c. Provided auxiliary manually cleaned screens for emergencies.	
d. Automatic control is desirable to prevent excess wear caused by continuous running. Use time clock or differential head across screen to activate the screen.	
5. Handling of screening	
a. Hand cleaned screens should have platform for the operator to easily clean screening off.	
b. Drains should be in both platform and storage areas.	
c. If screens are in deep its then approaches from above must be wide and suitable for elevation of collected materials.	
d. Water can be used to both collect screenings and slice them to grinders	
e. Grinders must be protected from metal and rocks with a magnet and hopper to remove these materials.	
f. Normally screens should be permanently removed from waste stream, but flexibility to return screenings to wastestream ahead of bar screens should be provided.	Slide 6-39: Screenings sluced to screenings/sludge mixing tank with emergency overflow ahead of the bar screens. See Fig. 6.13
g. May be dewatered with fixed or rotary screens or by centrifuges	

Lesson Outline	Illustrations/Key Points
h. If screenings are to be incinerated, they should be mixed with sludge to aid burning.	Slide 6-41: Flexibility to permit incineration or trucking of screening/sludge mixture if centrifuge capacity is reduced.
E. Comminutors	See Figure 6.14
1. If not preceeded by grit removal, then gravel traps should be provided to protect cutting teeth.	
2. Should be able to isolate comminutors from flow with slide gates.	
3. If multiple comminutors are not used a by-pass channel should be provided. If flow exceeds comminutor design flow, then excess is diverted.	
4. An elevated motor may be advisable if flooding of the area is anticipated.	
F. Effect of storm flows in combined sewers.	
1. After low, dry periods, a storm can flush tremendous quantities of screenings and grit out of a combined sewer system.	
2. The treatment system must be designed anticipated this type of slug loading of debris.	
3. Mechanically bar screens are preferred over comminutors.	
IV. Grit Collectors.	
A. Theoretical Considerations.	
1. Based on settling of discrete, non-flaccuant particles (Class I sedimentation)	Slide 1-3: Class I sedimentation: settling of particles in a suspension of low solids concentration. Particles settle discretely and there is no significant interaction with neighboring particles.
	Slide 1-4: A discrete particle placed in a quiescent fluid will accelerate until fluid drag reaches equilibrium with the driving force acting on the particle. At equilibrium, the particle settles at a uniform velocity (the terminal velocity).

Lesson Outline	Illustrations/Key Points
2. Class I sedimentation characteristics	Slide 1-5: Characteristics of Class I sedimentation.
a. The settling of particles with uniform terminal velocities, VC	
b. Stoke's Law relates VC to the force of gravity, the difference between fluid and particle density, particle volume and viscosity $$V_c = \frac{g\,(P_g - p)\,d^2}{18\,u}$$	
c. In grit tank design, select a particle with Vc and design the basin so that all particles with terminal velocity equal to a greater than Vc will be removed. The rate at which clarified effluent is produced is: $$Q = AVc$$ where A is the surface area of the grit tank and : $$Vc = \frac{Q}{A}$$ where $\frac{Q}{A}$ is the overflow rate (gal/ ft'd) which is equivalent to settling velocity.	
d. $Vc = \frac{Q}{A}$ indicates that the flow capacity in a grit tank is independent of depth.	
3. Grit tank design considerations	Slide 1-6: Grit tank design considerations.
a. Since Vc equals OR, particles with terminal velocities greater than Vc will be completely removed.	
b. Particles with settling velocities less than Vc will be removed in the ratio: $$Xr = \frac{Vp}{Vc}$$ where Xr is the fraction of particles with settling velocity Vp that are removed.	

Lesson Outline	Illustrations/Key Points
c. Total removal 1-Xc = fraction of particles with velocity Vp greater than Vc $\leq \frac{Vp}{Vc} \Delta X$ = fraction of particles removed with Vp less than Vc	
B. Operational Considerations	
1. Is desirable to place them ahead of influent pumps to protect the latter from abrasion. But is usually not possible because of the depth at which the tanks would have to be installed.	Slide 6-65: Locationg grit tanks tanks between influent pumps and primary sedimentation tanks. See Figure 6.15
2. In aerated grit chambers (the most popular form) velocity of roll governs size of particles removed. Liquid flow should complement air roll and air distribution should provide a spiral roll.	Slide 6-74: Aerated grit tanks, hoppers on far wall.
3. Variable air flow swing diffusers provide roll velocity control and are easily removed for service.	Slide 6-75: Swing diffusers in aerated grit tank.
4. Foam suppression from water sprayers is necessary.	Slide 6-73: Foam supression system consisting of water spray from nozzles. See Figure 6.16
5. Provide multiple hoppers and grit removal pumps for each grit tank.	Slide 6-68: Schematic of grit pump system. This first hopper in each tank has its own grit pump. See Figure 6.17
a. Use air and water agitation to stir up grit in each hopper. Air agitation is run to stir up grit, pumps are turned on, water is then used to keep grit in motion until the pump cycle is over.	Slide 2-21: Piping from individual grit pumps connecting with a common header
b. The first hopper should have its own grit pump and cyclone separator, as this hopper receives more grit than the rest. The grit pump should also be run continuously.	Slide 2-22: Cyclone separator on grit tank. Slide 6-69: Grit pump control schematic. Note interlock of grit agitation and pump control. See Figure 6.18
c. Grit pumps should operate under control scheme that allows for variable frequency and duration of operation. Interlock agitation with pump control.	Slide 6-67: Grit pumps located directly underneath grit tanks to facilitate pumping. See Figure 6.19
d. Diaphragm pumps are useful for grit removal. Should be no interconnections between pumps to facilitate changing pumps.	

Lesson Outline	Illustrations/Key Points
e. Gallery to house grit pumps is recommended. f. Grit can be difficult to remove so suction end of pump and tank drain should be kept close to each other to maintain a good positive head. Rectangular tanks permit this operation. 6. Piping should be designed for ease of maintenance. Pump suction line should be carried all the way to surface. Should be no 90 degree elbows and no long vertical runs in piping. Long radius elbows and flushing connections will help alleviate blockage and wear. Mechanical couplings should be used at all pipe fittings. 7. Grit dewatering a. Provide 2 grit pipes and dewaters for each grit tank. b. Overflow from dewaterers directed into flow ahead of tank to capture and remaining grit. c. Pass overflow through hydrosieves to catch the lighter debris that may not be captured in the tank or removed by the separator. 8. Where feasible, hydraulic handling of grit should be used to decrease costs and increase ease of handling. 9. Grit chambers in deep pits should be provided with mechanical equipment for hoisting grit to ground level. a. Chambers should have stairway with adequate ventilation and lighting. b. Provide sufficient drains and hard surfaces. c. Provide adequate supply of water under pressure.	Slide 6-71: Schematic of grit tank cyclonic separators with 2 hydrosieves (center of exhibit) that remove light material from overflow. Dewatered grit is dumped into a hopper and then trucked to incinerator. See Figure 6.20 Slide 6-76: Photo cyclonic separator. Slide 6-77: Photo of grit hopper discharge in gallery beneath the cyclone separators.

Lesson Outline	Illustrations/Key Points
10. Grit tanks serving combined sewer systems should be designed to handle 20 to 30 times the average quantities of grit normally received in dry periods	
V. Raw Wastewater Pumps	
A. The capacity to divert raw wastewater flow to any combination of pumps should be a part of design.	
1. Each pump and its channel section should be capable of being isolated from the rest of system using slide gates. Drains should be included for each isolated section.	
2. The minimum net suction head on each pump should be the minimum level center line of the pump impeller.	
B. A sump ahead of the influent pumps can collect grip and other debris.	
C. Variable speed pumps and parshall flumes can be used to control the pump throttling. If bar screen interfere with the water surface measurement in Parshall flumes, flow controllers on the discharge end of variable speed pumps can be used. These will maintain a constant flow by varying the pump speed.	
D. Influent pump horsepower can be saved by allowing the level in the downstream sump to rise during high flow periods which will reduce the head the pump has to pull against.	
E. Pump controllers should be capable of modulating severe inflow fluctuations so that flow to treatment processes are increased or decreased gradually.	

UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION

UNIT 7

UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION - UNIT 7

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Primary Sedimentation

Instructional Goal: To develop in the student an awareness of operational considerations in the design of primary sedimentation works.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Review general theory of primary sedimentation
- Show by examples operational features of primary sedimentation works

UNIT PROCESS DESIGN- PRIMARY SEDIMENTATION - UNIT 7

OBJECTIVES

At the conclusion of this presentation the participant will be able to:

- Define Primary sedimentation and Class II sedimentation.
- Discuss the importance of proper sedimentation tank sizing and the pros and cons of rectangular versus circular tanks.
- Design efficient inflow and equalization channels.
- List three advantages of submerged launderers over overflow weirs.
- List the attributes of air spray scum collection.
- Design efficient scum collection systems.
- Discuss the characteristics of a good sludge collection and removal system.
- Identify three methods of controlling sludge pumping.
- Design efficient, operable sludge piping systems.

UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION - UNIT 7

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	Sight glass on suction end of sludge pump	-102
7.4	Built in sludge handling flexibility	-95

Tables

(none)

Instructors Presentation Guide

Unit of Instruction 7:
Unit Process Design - Primary Sedimentation

Lesson Outline	Illustrations/Key Points
I. General Discussion of Primary Sedimentation	
A. Define Primary Sedimentation - To remove settleable solids from waste stream reducing suspended solids concentration.	Slide 1-3 - Sedimentation regimes
1. Gravity 2. Flocculation	Slide 1-4 Particle paths in sedimentation
B. Define Class II Sedimentation	Slide 1-7 - Class II Sedimentatio
1. Low concentrations of flocculant particles seperate from a liquid.	
C. Class II Sedimentation is a function of retention time as well as overflow rate.	Slide 1-9 - Retention time
D. Performance of sed tanks is best predicted from laboratory settling tanks.	Slide 1-8 - Laboratory evaluation of Class II sedimentation
1. Affects design of primary clarifiers, as well.	Slide 1-10 - Equation of removal
II. Tank Surface Area and Geometry	
A. Surface area is based on overflow rate.	Slide 1-11 - Design for foculent settling
1. Laboratory data 2. Previous experience	Slide 1-12 - Design of slurry settlers
B. Depth is based on desired retention time.	
C. Length of overflow weirs is based on a specified overflow rate.	
D. Rectangular or circular tanks can be used.	
1. Rectangular require less surface area than circular tanks when multiple are used.	

Lesson Outline	Illustrations/Key Points
2. Rectangular tanks can be intervested with preaeration and aeration tanks in activated sludge plants. 3. Rectangular tanks, in multiple, allow for short suction piping between the tank and sludge pumps. a. Permits development of maximum positive suction head. b. Reduces probability of pump clogging. 4. Sludge removal methods vary with tank shape. a. Rectangular - countercurrent withdrawal b. Circular - Central withdrawal III. Tank Size A. Depends on flow requirements. B. Should be sufficient hydraulic capacity to pass peak plant flow even if one unit is out of service. C. Detention times vary. 1. One to one and one-half hours with secondary treatment involved. 2. One and one-half to two hours for primary treatment only. 3. Liquid depth of 9-10 feet is good to avoid excessive detention times. IV. Inlet Characteristics A. Should never exceed 1.5 to 2.0 feet per second. 1. May necessitate aeration of influent channels to keep solids in suspension.	

Lesson Outline	Illustrations/Key Points
a. Shearfusers, recessed into the channels to prevent debris accumulation, may be used.	
b. Each shearfuser should have its own air supply in order to assure that device is kept free of obstructions.	
B. Inlet gates should be provided with target baffles to minimize short circuiting.	
1. Tanks themselves should have finger baffles to minimize short circuiting.	
C. Water level in PST can be controlled with modulating sluice gates.	
1. Should maintain preset water level.	
V. Equalization of Flow	
A. Wastewater must be distributed equally among all PST's.	
B. Can utilize flow splitter boxes with division weirs to equalize flow.	
C. In larger plants distribution channels to equalize flow can be substituted.	
1. Design for a minimum differential head loss down the channel at all flows.	
2. Inlet from channel to each PST should be designed with very small head loss to insure that each tank receives the same amount of flow.	
D. Hydraulic control system at the effluent end of each tank can be used to distribute flow equally.	Slide 6-'78 - Twelve primary sed tanks being operated, in parallel eff. a common influent channel. See Figure 7.1
1. Has been used successfuly on battery of 12 primary clarifiers at a wastewater treatment plant in Sacramento, California.	Slide 6-81 - Section of primary sed tank showing submerged launder system at effluent and of tank.
a. System consisted of submerged launderers with 2 1/2" diameter orifices.	

Lesson Outline	Illustrations/Key Points
b. Designs to have 18" head loss between water surface in tank and effluent channel at peak flow	
c. Common channel discharged through a control gate.	Slide 6-79 - Schematic demonstrating sed tank water level control mechanism which activates the effluent control gate as the level in the tank attempts to rise or fall.
(1) Gate closed at no flow with water level in effluent channel and sed tank the same.	
(2) As flow increased gate was opened proportionately and level in channel dropped to compensate for head losses in orifices.	
(3) Gate totally open at peak flow and level in channel was 18" below level in settling tank.	
d. If one tank began accepting more flow head would rise in tank and flow would redistribute amongst other tanks.	Slide 6-80 - Demonstrates sed tank water level control mechanism which activates effluent control variable speed pump as the level in the tank attempts to rise or fall.
IV. Effluent Launderers	
A. An effluent launderer is . . .	
B. Should cover a minimum of 25-30% of sed tank area to minimize effects of upward flow velocities on settled solids.	
C. Submerged launderers have some advantages over overflows weirs	Slide 6-82 - Submerged launderers in a PST.
1. Reduce free-fall turbulence. Minimizes release of odor from primary effluent.	
2. By discharging below surface of a settling basin reduces floatables in the effluent.	
3. Reduces algae and slime growth on tank edges.	

Lesson Outline	Illustrations/Key Points
VII. Scum Collection and Transfer	
A. Accomplished either by skimming off the surface, or by flights at the effluent end of a rectangular tank.	
1. In circular tanks skimmers are usually attached to the sludge removal mechanism.	
2. In rectangular tanks scum is moved by flights to a point where it is trapped by baffles.	
3. Scum can be moved by water or air sprays.	Slide 6-85 - Water Spray for scum collection.
a. Moved to point of collection at head of rectangular tank.	
b. Minimizes scum pumping and locates collection far from effluent end.	
c. Air spray may be more effective than water spray.	Slide 6-83 - Scum accumulation on sed tank using water sprayers.
(1) Air can use same plumbing as water.	Slide 6-84 - Same site as previou slide after installation of air jets for scum collection. Point out difference.
(2) Air can be run at 4.0 csm at 3.5 p.s.i. or 3.5 csm at 4.0 p.s.i. at nozzle.	
(3) Use of air prevents clogging.	
(4) Air spray must be protected from wind.	
(5) Air may have to be augmented with water during peak flows in large plants.	
4. Collected scum should be pumped by positive displacement pumps to the scum processing tanks.	
a. Manifold the piping for flexibility to allow separate scum disposal.	
(1) Scum may be piped to either digesters or scum thickeners.	

Lesson Outline	Illustrations/Key Points
b. Glass lined pipe should be used for all scum piping to minimize grease build-up.	
VIII. Sludge Collection	
A. Sludge is usually collected in rectangular tanks.	
1. Use endless conveyor chains.	
B. Conveyor chains attached to full tank width flights at various intervals.	
C. Longitudinal flights convey sludge to cross collectors at inlet end of tank.	
D. At inlet end, sludge conveyors move sludge to hoppers.	
1. Flight 2. Screws	
E. Sludge collector should remain submerged over the entire length of travel.	
1. Submergence prolongs life of flights by eliminating alternate wet-dry exposure periods.	
2. Redwood is most common flight construction material however, Douglas fir lasts equally as long and is a stronger, more durable wood in the prescribed environment.	
F. Sludge collectors should be equipped with manual adjust variable speed drives.	
1. Allows for optimum speed setting.	
G. Operator should be given flexibility to run the sludge collection system either continuously or intermittently.	
H. Recently developed non-metallic chains are an attractive alternative to metal chains.	

Lesson Outline	Illustrations/Key Points
1. Non metallic chains are easier to handle than metallic chains since the non-metallic chains are one-fourth the weight of the metal chains.	
2. Four-year study comparing non-metallic to metallic chains has been conducted. (Ref.: Nedinsky and Quandt, 1980)	
a. Molded links joined together with snap-lock pins saved time and man-power cost.	
b. Lighter weight non-metallic chains were more easily strung across flights.	
c. Less maintenance was required on flight wear shoes where non-metallic chains were used.	
d. Metal chains took twice as long to remove as the non-metallic since the metal chains had to be cut with torches and then winched from the tank.	
e. It was necessary to add weight to the reduced flights to keep them from floating out of the basin due to the lessened weight of interconnecting non-metallic chains.	
3. During the four-year study it was concluded that non-metallic chains performed as well as metallic chains.	
IX. Sludge Removal	
A. Sludge should be removed from hoppers by positive displacement pumps equipped with variable speed drives.	
B. If progressive cavity pumps are used, maximum speed should be below 300 rpm.	Slide 6-99 - View of progressive cavity pump used for primary sludge.

Lesson Outline	Illustrations/Key Points
1. Utilization of one more stage than the design requires will result in longer life and less maintenance on progressive cavity pumps.	
a. Wear is reduced by lowering back pressures within the cavities.	Slide 6-101 - Pressure sensing device for protecting pumps from excessive back pressures.
C. On positive pressure pumps it is important to measure pressure at the discharge end.	
a. A pressure build-up at the discharge end may result in pump destruction.	
b. Measurement gauge should be capable of instituting pump shut-down when excessive pressures are sensed.	
D. Pumping system should be designed so that one pump is connected directly to each sludge hopper.	Slide 6-94 - Sedimentation tank/ sludge pumping system. See Figure 7.2
1. Undesirable to use a single pump for more than one hopper since flow from each hopper could not be controlled simultaneously.	Slide 6-98 - Primary sedimentatio gallery for system shown in Slide 6-94.
E. Sludge pumping can be controlled in three ways.	Slide 6-96 - Sludge pump control system. See Figure 7.3
1. The sludge blanket level can be monitored with shutdown occuring when sludge density reaches a preset level.	
2. Sludge pumping can be continuous with speed modulation based on the sludge blanket level.	
3. Timer can be set to start/stop pump at preset times.	
4. It is advisable to have at least two of these three options available to the operator to provide maximum system flexibility.	
F. Sight glass should be provided in sludge suction lines.	Slide 6-102 - Sight glass on suction end of sludge pump.

Lesson Outline	Illustrations/Key Points
1. Assists operators in determining condition of primary sludge.	
2. May be used for flow verification.	
3. Should be located on suction end of pumps due to high pressures that can build up on the discharged side.	
G. Sludge flow and density should be measured and recorded to provide information on solids balance.	
H. Sludge piping should be designed for flexibility and reliability.	Slide 6-95 - Sludge piping systems. See Figure 7.4
1. Two glass lined pipes should be provided and each pump should be connected to both lines.	
2. High sludge velocities (4 - 6 fps) are desirable in the piping.	
a. Reduce buildup	
b. Achieve high heat transfer rates in the sludge heaters.	
3. It is desirable to keep sludge from the anaerobic digesters circulating through the primary sludge lines.	
a. Prevents grease buildup in the lines.	
b. Assists in blending the sludges.	
4. Heat exchangers for raw sludge and recirculated sludge decreases buildup of grease in transport piping.	
5. In order to maintain desired characteristics and efficiency piping should be insulated after heating.	

UNIT PROCESS DESIGN - AERATION BASINS

UNIT 8

UNIT PROCESS DESIGN - AERATION BASINS - UNIT 8

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Activated Sludge

Instructional Goal: To develop in the student an awareness of operational considerations in the design of waste activated sludge facilities.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Review of general theory of biological processes in waste activated sludge treatment.
- Show by examples operational features of waste activated sludge aeration basins.

UNIT PROCESS DESIGN - AERATION BASINS - UNIT 8

OBJECTIVES

At the conclusion of this presentation, the participant should be able to:

- Identify the goals of a designer in providing an activated sludge unit process.
- Write the formula for maintenance of a constant food to microorganism ratio, and explain its significance.
- Describe the relationship of growth rate of microorganism to solids retention time.
- Describe the relationship of food to microorganism ratio to solids retention time.
- Write an explanation of Henry's Law including an identification of its importance to the Design Engineer.
- Discuss oxygen transfer and the effects of bubble size in transfer efficiency.
- List four differing types of activated sludge treatment and describe each.
- Discuss the option and design characteristics for an activated sludge facility.
- List at least four "design hints" dealing with influent channels.
- Discuss techniques to provide flexibility in an activated sludge system.
- Look up six elements which should be metered in any activated sludge system.
- Discuss the criticality of aeration and list three "design hints" which facilitate operation and maintenance.
- Describe foam control techniques.
- List four elements which should be included in a facility to assist in maintenance and repair.

UNIT PROCESS DESIGN - ACTIVATED SLUDGE - UNIT 8

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(none)

Instructors Presentation Guide

Unit of Instruction 8
Unit Process Design - Activated Sludge

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. All biological unit processes employ bacteria to oxidize organic materials in wastewater.	
1. Reaction is:	Slide 1-26: Overview of biologcal treatment using cartoon.
Organics + O_2 + Bacteria + Nutrients = New Bacteria + H_2O + CO_2	
B. The goal of wastewater treatment is to minimize the organics in the effluent stream.	
1. Done by insuring that the organics in the feed are the rate-limiting reactant.	Slide 1-34: Activated Sludge control
C. Goal of treatment plant operator is to control growth rate of the microorganisms to produce the desired effluent quality.	Slide 1-27: Graph of Microbial Growth Rate.
D. Goal of designer is to provide operator with the flexibility needed to maintain the desired organism growth rate despite wide variation in influent flow rate and quality.	
II. Methods to Maintain Activated Sludge	
A. One method of maintaining the desired growth rate is to maintain a constant food to microorganism ratio (F:M).	
1. Parameter defined as:	
$U = \frac{\Delta S/\Delta t}{x_t}$	Slide 1-35: F/M Defined.
When U - Food to microorganism ratio. $\Delta S/\Delta t$ - Mass of substrate utilized per unit of time. x_t - Mass of organisms in the system.	

Lesson Outline	Illustrations/Key Points
2. No convenient method to determine mass of organism in system, x_t.	
a. Usually approximated using the system suspended solids.	
3. Growth rate can be controlled by manipulating the biological solids retention time (SRT).	
a. Defined as: $\theta_i = \frac{x_t}{(\Delta x/\Delta t)}$	Slide 1-36: SRT Defined.
Where: θ_i = Solids Retention Time; $\Delta x/\Delta t$ = Mass of solids lost per unit time by intentional and unintentional wastage; x_t = Mass of organisms in the system.	
b. Easier to approach because it does not require determination of the organisms in the system.	
4. Food to microorganism ratio can be related to SRT	
a. Relationship: $\frac{1}{\theta_c} = Y\,(u) - K_d$	Slide 1-37: Relationship between SM and SRT.
Where: $Y\,(u)$ = Microbial yield coefficient; K_d = Microbial decay coefficient	
III. Gas Transfer - Oxygen Flow	
A. The rate of gas transfer, primarily oxygen, into the liquid phase is an important design consideration.	
B. Henry's Law described the solubility characteristics of oxygen and other gases.	Slide 1-20: Henry's Law.
1. Law is that the saturation concentration of oxygen in water is proportional to its partial pressure in the gas phase.	
a. For calculation, oxygen transfer is assumed to occur across a laminar boundary layer.	

Lesson Outline	Illustrations/Key Points
b. Based on this assumption the rate of oxygen transfer can be described as: $N = K_{La} (Cs - C)$ Where: N = Rate of oxygen transfer K_{La} = Mass transfer coefficient C = Concentration of oxygen in bulk liquid Cs = Oxygen saturation concentration	
c. Rate of oxygen transfer is affected by a number of factors: 1) Solubility of oxygen in liquid affects the driving force directly influencing the rate of transfer. (a) Function of temperature, partial pressure, and salinity of the solution. (b) The above factors each can indirectly affect the rate of oxygen transfer. 2) Bubble size affects transfer. Smaller sized bubbles will provide larger transfer area, and thus a higher mass transfer rate: (a) Bubble size is affected by flow rate - bubbles tend tc coalesce at high flow rates. (b) Bubble size is affected by the properties of the suspending medium particularly surface tension, and the presence of a solid phase. (c) Type of aeration equipment can determine bubble size in a basir	Slide 1-22: Table of Factors Affecting Oxygen Transfer
d. Effects of liquid-phase properties on mass transfer are considered using a factor which is the ratio of K_{La} in wastewater to K_{La} in pure water.	

Lesson Outline	Illustrations/Key Points
IV. Types of Activated Sludge Treatment	
A. The activated sludge process is one of the most commonly used biological processes for the treatment of domestic and industrial wastewaters.	Slide 1-28: Classification of Activated Sludge Processes.
1. Can be classified in various ways:	
a. Mixing regimen (plug flow versus completely mixed)	
b. Contacting pattern (step feed versus contact stabilization)	
c. Microbial growth rate (conventional versus extended aeration)	
d. Source of oxygen (air versus pure oxygen)	
B. Completely mixed process is characterized by a uniform concentration of substrate and microbial solids throughout the basin.	
1. Because concentration of organic substrate is low relative to microorganism mass, the process resists shock loads of soluble organics.	
a. Complete mixing dilutes low-level toxic shocks to sub-lethal levels.	
2. Kinetically system is at a disadvantage because biochemical oxidation occurs at a rate governed by the effluent concentration.	
C. Plug-flow is characterized by a decreasing substrate concentration and oxygen demand throughout the length of the tank.	Slide 1-30: Plug Flow (Activate Sludge)
1. Pure-oxygen systems use plug-flow by providing several reactors in series.	
2. A modification to this approach is tapered aeration.	
a. Air supply is decreased near the outlet end of the tank in the same way air is regulated in pure oxygen systems.	

Lesson Outline	Illustrations/Key Points
b. One advantage of tapered air is its ability to resist bleed-through of substrate during shock loads.	
D. Extended aeration is a modification of the activated sludge process which forces the microbial population to respire endogenously.	Slide 1-31: Extended Aeration
1. Necessitates a relatively low organic loading and long aeration time.	
a. Applicable only at small treatment plants.	
b. Long solids retention time reduces sludge production. Applicable to package plants that receive minimal maintenance.	
E. Contact stabilization utilizes the ability of microorganisms to rapidly take up and store substrate.	
1. A 20 to 40 minute contact time between activated sludge and incoming wastewater is provided.	
2. Followed by solids/liquid separation after which the sludge is reaerated in a separate basin while the microorganism oxidize the stored organics.	
a. This process reduces the aeration volume requirements compared to that needed in conventional activated sludge.	
b. Must be careful to insure that synthesis or washout does not occur in the contact tank.	
c. Must be careful to insure that organics are oxidized completely during reaeration.	
F. Step aeration is a modification in which the feed is introduced at a number of points along the length of the aeration basin.	Slide 1-33: Step Aeration
1. Spreads oxygen demand throughout the length of the basin.	

Lesson Outline	Illustrations/Key Points
2. Permits flexibility in mode of operation from plug flow to contact stabilization.	
3. Produces a better settling sludge for a given loading rate.	
4. Temporarily can reduce the solids loading to the clarifier during settling problems.	
V. Optimal Design	
A. Should be based on pilot studies which select the solids retention time or food to microorganism ratio as determined by performance, oxygen consumption, solids production, and settling data.	Slide 1-38; Activated Sludge Design Considerations.
B. Once the F:M or SRT have been established, the mixed liquor suspended solids level, detention time, and desired range or recycle rates can be computed from design equations.	
C. In the absence of pilot data equipment can be sized using an assumed F:M or SRT.	
1. In this case it is necessary to estimate the solids production and oxygen requirements based on experience with similar wastewaters.	
VI. Influent Distribution	
A. Very important that influent be equally distributed to all tanks in use.	
1. Provide equal head loss to each reactor.	
2. Keep velocities low to assist in equal distribution.	
3. Strive to prevent solids deposition	
a. Provide air agitation in influent channels.	Slide 6-116: Influent settled sewage channel using shear fuse in channel bottom to keep suspended solids in motion.
4. Design channels such that as expansion of treatment capacity occurs equal distribution of wastewater among additional aeration basins will continue.	

Lesson Outline	Illustrations/Key Points
5. Make provisions for bypassing the primary settling tanks and discharging raw wastewater directly to the reactors following pretreatment.	
6. Provide simple manual adjustments to enhance operational flexibility.	
VII. Inlets/Outlets	
A. Each inlet/outlet for each aeration basin should have valves, gates, stop plates, weirs, or other devices to permit flow control to any unit while maintaining a constant liquid level.	
B. If any system is taken out of service the system hydraulics should permit the maximum instantaneous hydraulic load to be carried by the remaining units.	
C. Foam suppression should be used in influent channels.	
1. Water sprays recommended.	
D. Surfaces over which liquid passes should be free from obstructions so that foam and scum can easily pass through the channel system.	
VIII. Designing for Flexibility	
A. Design the system to be run in different modes (such as plug flow, step aeration, and contact stabilization).	Slide 6-115: Overview of aeration basin system.
1. Especially helpful in temperate zones where temperature fluctuations can make periodic changes in process desirable.	Slide 6-105: Two - 4 pass aeration basins with flexibility to hold settled sewage at 12 points in each basin. The influent channel wraps completely around the two basins. See Figure 8.1.
2. Design influent channels capable of feeding the basins at several locations.	
B. Pure oxygen plants, run in the same fashion, as aerated plants should be provided the same flexibility.	Slide 6-118: Slide gates at feed locations on aeration basin. Eight gates may be used to control the amount of influent entering at each point.
1. Especially needed when subjected to seasonal loading.	Slide 6-120: Center for automated control of flow into aeration basins. Panel on fall wall shows how many slide gates are open at each point of sewage fee
2. Should be multiple oxygen compressors if step aeration capabilities will be included.	

Lesson Outline	Illustrations/Key Points
C. Multiple aeration basins provide flexibility to treat minimal flows of initial on-line use while providing the capacity to treat full-scale flows later on.	This gives the operator instantaneous knowledge of the flow pattern being used. Also, shows amount of sewage going into the aeration basins at each influent point.
D. Dimensions of each tank should be adequate to maintain effective mixing and utilization of air.	
1. Liquid depths should range from 10 to 20 ft.	
E. Flow velocities should be high enough to prevent solids deposition.	
F. Fillets should be provided around the aeration tanks where wall and bottom meet.	Slide 6-121: Pure oxygen plant showing flexibility of input to aeration basins. See Figure 8.2
G. Basins should have freeboard not less than 18".	Slide 6-133: Multiple oxygen compressors to accommodate step aeration capabilities. See Figure 8.3.
1. Tanks with mechanical aerators require 3 to 5 feet of free board.	
IX. Metering and Sampling	
A. Must provide valid information to operator for him to maintain proper control of system.	
B. Should provide meters for the following:	
1. Return activated sludge (RAS) to each aerator.	
2. Sludge withdrawal rate from each clarifier.	
3. Waste activated sludge from clarifier.	
4. Influent flow to each aeration basin.	
5. Mixed liquor suspended solids (MLSS) flow to each clarifier.	
6. Air discharge in each aeration basin. Air flow rate indicator for each pass is desirable.	
C. Design RAS discharge above the water level in the aeration tank to allow visual inspection of sludge loading.	
X. Aeration of Activated Sludge	

Lesson Outline	Illustrations/Key Points
A. Aeration is critical since it provides both the oxygen required for microbial respiration and the turbulence necessary to mix influent wastewater with the MLSS.	
1. Spacing of diffusers should be done to meet the oxygen requirements throughout the length of the tank.	
2. Should be designed to facilitate respacing without major revisions to air header piping.	
3. Should be able to remove diffusers without dewatering the tank or shutting off the air supply to other diffusers in the tank.	
B. Be certain to provide adequate mixing throughout the total practical range of aeration intensity.	
C. Avoid diffuser placement patterns that can create unmixed cores or dead spots.	
D. Provide sufficient air compressor capacity.	Slide 6-126: Blower (rt) and RAS (lft) pumps. Both are located in gallery beneath basins to minimize piping and reduce required blower capacity
1. Standby capacity must be provided for maintenance and repair under maximum uptake requirements.	
E. Provide sufficient intake airfiltering for the selected dissolution equipment.	Slide 6-125: Blower for aeration basins.
1. For example, use a bag filter for fine bubble diffusers.	
F. In cold climates the specified capacity for the motor drive should be based on an ambient intake air temperature that may be well below zero degrees F.	
1. May require oversizing motor.	
2. May require reducing rate of air delivery to prevent overheating or damage to the motor.	
G. Air flow into basins can be controlled by a dissolved oxygen (DO) feedback mechanism.	Slide 6-127: Do feedback control system gauges.
1. Probes measuring DO in basin feedback to open or close air control valve depending on amount of DO in MLSS.	Slide 6-128: Graphs showing diurnal variation of air flow (red) and constant DO concentrations (green) into 2 aeration basins.

Lesson Outline	Illustrations/Key Points
2. Alters pressure on main distribution system increasing or decreasing throttling on blowers.	
3. Is an energy efficient system.	
4. Refines process control.	
H. Provide air control facilities that permit operator to vary aeration intensity to match loading, sludge quality, and process status requirements.	
XI. Foam Control on Aeration Basins	
A. Provide foam and scum control on the aeration basins.	
1. Water Spray Systems work well.	
2. Provide capability to introduce chlorine into the tanks to deal with Nicardia foam should it develop.	
B. In closed reactors, such as pure oxygen systems, provide both foam control and removal systems.	Slide 6-122: Scum protection system for pure oxygen. (See Figure 8.4).
1. Extra foam sprayers on pure oxygen reactors will insure that foam does not get into the oxygen return system.	
C. As a result of rapid decline in organic loading to a plant, scum production may be accelerated.	
1. Due to rapid decline in the food to microorganism ratio followed by the death of a large number of microorganisms.	
a. Float to surface and form a scum.	
2. If decline in organic loading can be anticipated extra sludge can be wasted and the F/M ratio will not drop low enough to cause massive microbial death.	
XII. Maintenance and Repair	Slide 6-134: Recessed drain gates to facilitate drainage in aeration basin. (See Figure 8.5
A. Protect against loss of solids with isolation gates; intermediate drains, and the ability to pump channel contents into operating aeration basins.	Slide 6-135: Aeration basin drainage system. (See Figure 8.

Lesson Outline	Illustrations/Key Points
B. Provide sufficient tank bottom slope to encourage complete drainage. C. Provide washdown water supplies in addition to steam cleaning and compressed air capabilities. D. Provide utility power outlets at 120/220/440 volt delivery for use as required.	Slide 6-136: Schematic showing aeration basins, primary, and secondary sed tanks draining to a common sump and pump station. (See Figure 8.7)

UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION

UNIT 9

UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION - UNIT 9

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Secondary Sedimentation

Instructional Goal: To develop in the student an awareness of operational considerations in the design of secondary sedimentation works.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Review general design considerations for secondary sedimentation facilities
- Show by examples operational features of secondary sedimentation facilities

UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION - UNIT 9

OBJECTIVES

At the conclusion of this presentation the participant should be able to:

- Define the function of secondary sedimentation.
- Identify the pros and cons of various tank geometries.
- State the proper overflow rates for sedimentation tanks.
- Demonstrate an understanding of clarifier design requirements.
- Design efficient influent channels.
- State the importance of sample collection and identify acceptable techniques.
- Design scum handling equipment which is proper and efficient.
- Identify at least five "design hints" for overflow weirs.
- Design sludge collection and return systems which meet requirements and are relatively easy to operate.
- Describe adequate sludge control techniques and systems.
- List at least five elements which make maintenance and repair easier.

UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION - UNIT 9

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(none)

Instructors Presentation Guide

Unit of Instruction 9
Unit Process Design - Secondary Sedimentation

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Function of secondary sedimentation is to separate activated sludge solids from the mixed liquor discharged from an aeration basin.	
1. Critical step in the activated sludge treatment process.	
2. Intended to produce a final effluent that is low in BOD and suspended solids.	
3. Design must be sufficient to handle peak hydraulic loads.	
4. Design should be flexible to allow operator to modify process as unique treatment situations are encountered.	
II. Tank Geometry	
A. Activated sludge settling tanks may be either circular or rectangular.	
B. Circular tanks have some advantages	
1. Easier to achieve a good distribution of incoming flow while maintaining low horizontal velocities across the tank.	
2. Allow for the most rapid removal of solids.	
C. Rectangular tanks have some advantages.	
1. Sludge pumps can be positioned closer to the sludge discharge point resulting in reduction of line clogging by maintaining a maximum positive suction head on the pump.	
2. Require less area than circular.	
3. Can take advantage of common wall construction when expansion of settling facilities is required.	

Lesson Outline	Illustrations/Key Points
III. Overflow Rates	
A. Design tanks for relatively low (500 to 550 gpm) overflow rates.	
1. Most plants operate at relatively high mixed liquor suspended solids (MLSS) concentrations . Thus producing a thick sludge which settles out at rates slower than that of thin sludges.	
B. Design tanks to reduce automatically to 500 to 550gpm range during average flows even when tank is designed for peak hydraulic flows such as 1200 to 1500 gpm.	
IV. Clarifier Design.	
A. In larger treatment plants, must provide enough clarifiers to meet hydraulic loading and effluent quality requirements even though one tank may be removed from service.	
B. Each clarifier must be sufficiently deep for separation and concentration of sludge to occur	Slide 6-139: Arrangement of 16 center feed sed tanks at a large treatment facility. See Figure 9.1
1. Depths of 14 to 20 feet are the best.	
C. After optimum design requirements are met, at least two feet of depth should be added to assure sufficient area for consolidation of sludge.	
V. Influent Channels	
A. Design should insure an equal distribution of flows and solids.	
1. Create a maximum head loss at each tank inlet to achieve this distribution.	Slide 6-137: Provide sufficient head loss on rim feed inlets to insure equal distribution of MLSS to all tanks. See Figure 9.2
B. In order to avoid the scouring of settled solids by velocity currents from in-coming wastewater distribute the flow in tanks through multiple chambers that reduce the size of velocity currents.	
C. In center feed tanks the diameter of the stilling chamber should be 25 to 30% of that of the tank and should extend no more than 3 feet below the surface to avoid scouring deposited sludge from the sludge drawoff sump.	Slide 6-138: Typical MLSS distribution system for center feed tanks See Figure 9.3 Slide 6-153: Feed well on typical center feed secondary sed tank.

Lesson Outline	Illustrations/Key Points
VI. Sample Collection	
A. Should provide for convenient collection of representative samples for control testing and laboratory analysis.	
1. Automatic proportioning, refrigerated sample collectors are recommended.	
B. Flow meters should be provided to measure mixed liquor into and return sludge flow out of each clarifier.	
1. Flow meters should be coupled with control capability for the operator.	
C. A sampling station for the clarifier effluent will permit evaluation of the activated sludge system.	
VII. Scum Handling	
A. Scum collection is mandated on all Federally funded projects.	
B. Scum collection assists in production of a good quality final effluent.	
C. Influent scum collection should be provided in the influent distribution chambers.	
D. Skimmers are the most commonly used means of scum collection on the tank surface.	Slide 6-157: Scum removal system for sed tanks using submerged launders. See Figure 9.4
E. Scum pumping to digesters should be done using positive displacement pumps.	
F. Where scum is pumped to collection sumps or thickeners, centrifugal pumps may be used.	Slide 6-149: Lily pad skimmers that use continuous vacuum to remove scum. Several of these can be located in a sed tank and attached to flexible hose. They are blown by the wind to the area of greates scum accumulations.
G. All scum piping should be glass lined to reduce grease accumulation.	
VIII. Overflow Weirs	
A. Should be arranged to minimize upflow velocities and associated turbulence.	
B. For tanks larger than 100 feet in diameter two concentric weirs should be installed.	Slide 6-151: Dual overflow weir system on large secondary sed tank Designed to reduce upflow velocity into the weirs. Note: Observe railed cat-walk above each weir fo maintenance purposes.

Lesson Outline	Illustrations/Key Points
C. On circular clarifiers from 50-100 feet in diameter, weirs should be located about ¼ to 1/3 of the tank radius in from the outer tank wall.	
D. On rim feed tanks overflow weirs should be near the center of the tank.	Slides 6-146,147,148: Submerged launder systems for sed tank overflow.
E. On rectangular clarifiers, outlet and overflow weirs should be located across at least 1/3 of the total tank surface to minimize flow velocities.	Slide 6-140: Effluent collection system on a peripheral feed tank. See Figure 9.5
F. Strive to keep upflow velocities to a minimum.	Slide 6-161: Effluent collection system on center feed tanks. See Figure 9.6
G. Strive to keep weir loading per foot of length as low as possible.	Slide 6-142: Effluent collection system on center feed tanks. See Figure 9.7
	Slide 6-160: Illustration of hydraulic collection of sludge (dotted arrows). Note: Sludge remains at tank bottom until solids are drawn off below the center feed well. See Figure 9.8
VIX. Sludge Collection and Return	
A. Sludge collection from secondary sedimentation tank is best accomplished with hydraulic collectors.	
B. Specific gravity of biological sludges is too low to push along with flights.	
C. In hydraulic collection systems, the driving force is the static head between the liquid surface in the sedimentation tank and that in the feed well.	
1. In this type of set-up the collector pipes should remain along the bottom because the head is small.	
a. If pipes are brought up (for example, for observation) the head may be too little at low flow periods to pick up the sludge.	
b. This requires a much higher return flow during low flow than at peak flow.	
c. Orifices along the manifold should be sized differentially because those along the edge of the tank will pick up more sludge than those near the center.	

Lesson Outline	Illustrations/Key Points
d. Hydraulic capacity of sludge removal equipment should be adequate to remove sludge from the entire tank bottom area during each revolution or pass.	
D. Each set of tanks and clarifiers should have a separate return activated sludge (RAS) and waste activated sludge (WAS) facility including inter-group return and waste sludge capabilities.	Slide 6-158: Location of RAS pumps on a battery of secondary sed tanks See Figure 9.9
1. Capacity to do either simultaneously should be a part of design.	
2. Should design operation for a 100% return sludge capacity.	
a. Applies to all flow regimens to which the plant may be exposed.	
3. Multiple pumps, with remote discharge control, should be included.	Slide 6-156: Each sed tank is equipped with 2 RAS pumps for flexibility and back-up. See Figure 9.10
a. Pumps should be able to provide 100% return capacity with any single pump out of service.	
4 Suction and discharge piping on the RAS should be at least 4" in diameter.	Slide 6-154, 155: Typical set-up of battery of RAS pumps.
a. Piping should allow maintenance of no less than 2 fps sludge velocity when RAS facility is operating at normal return rates.	
5. Return sludge piping may be terminated above the aeration tank liquid level to permit observation and sampling.	
6. All critical sludge transfer lines should be constructed in duplicate to allow for flexibility in rerouting sludge flow.	
7. All activated sludge treatment plants, except small package plants, should be provided with an automatic RAS controller.	
a. One type of controller senses wastewater and return sludge flow in addition to MLSS and RAS. Operator adjusts controller set-point to the required RAS percentage or the RAS concentration (preferably). With this information the automated controller can regulate RAS discharge rates continuously to meet the process demands of normal wastewater flows.	

Lesson Outline	Illustrations/Key Points
b. A second type RAS controller uses a weir in the return line. The weir controls flow between a wet well and an RAS return channel.	Slide 6-144: RAS pump system and aeration basin compressor located on same gallery. RAS uses weir control to govern the sludge pumping rate. See Figure 9.11
(1) Weir governs sludge pumping rate - when head on weir changes the sludge flow pumping rate changes accordingly.	
(2) By calibrating the weir for the required percentage return flow, actual sludge flow rates will be automatically adjusted for necessary percentage as wastewater flows change daily.	
8. WAS system should be able to handle a maximum of not less than 25 percent of the average wastewater flow in order to enhance flexibility.	
a. Can be accomplished in two ways:	
(1) By having a large volume backup pumping system or,	
(2) By having a valved bypass between the WAS and RAS lines. (This system can be used temporarily for wasting)	
9. Size of the waste sludge pumps and meters small enough (3% to 10% of RAS flow) to assure proper wasting control.	
a. Both sludge concentration and flow measurements are needed for correct control.	
10. An automatic waste sludge controller can improve plant performance.	
a. Measure concentration and flow	
b. Converts to pounds or sludge units.	
c. Wastes the mass according to the set point adjustment of the operator.	
11. WAS removal should be self-correcting to adjust automatically for changes in sludge consistency.	Slide 6-163: Computer control of WAS. See Figure 9.12

Lesson Outline	Illustrations/Key Points

a. System should be independent of changes that may occur in the return sludge lines.

b. Do not rely on sidestreams off the RAS piping without separate control for WAS.

c. Avoid branching the waste sludge line off a common return-waste discharge header.

d. Use separate return and waste pumps.

12. Provide emergency storage for waste sludge.

a. A tie and valve can be added to the WAS line to routesludge to the primary clarifiers in the event that disposal capabilities are temporarily reduced.

X. Maintenance and Repair

A. Providing adequate means to take settling tanks out of service will encourage maintenance.

B. A transfer pump and piping system capable of emptying any tank within an 8 hour shift is desirable.

C. Protection against loss of solids can be acquired by providing capability to pump sedimentation tank contents into the aeration basins.

D. If hydraulic draw-off of sludge is in use, the use of a drain in the center of a tank is impaired.

1. Problem can be alleviated by sloping tank bottom from center to tank periphery. Drains can then be located at the periphery and can be easily cleaned.

E. All portions of the secondary sedimentation system should be capable of being isolated for maintenance and repairs.

F. Inlets and outlets should be sealed with slide or sludge gates.

G. Adequate washdown water should be provided.

Lesson Outline	Illustrations/Key Points
H. Steam cleaning means and support paraphernalia along with the provision of compressed air may be appropriate.	
I. Utility power outlets of 120/240/440 volt are helpful to the operator.	

OPERATIONAL CONSIDERATIONS IN WASTEWATER
TREATMENT PLANT DESIGN - UNIT 9A

INSTRUCTOR LESSON PLAN

Unit Title: Design and Operational Criteria for Thickening Biological Sludges; Appendix 9A

Instructional Goal: To present ways for the student to succesfully utilize the state point concept in the design of aeration basins and secondary clarifiers.

Method of Instruction: Lecture/Slides

Lesson Length: 1 hour

Instructional Resources:

Student Manual print materials
2 x 2 slides (there are no viewgraphs for figures or tables for this appendix in the Student Manual)
Unit Objectives

General Plan of Instruction:

- Present background and theory
- Describe system design features
- The lecture will not cover the experimental approach and apparatus, the illustrative design example, or operational state analysis and control that are included in the Student Manual.

DESIGN AND OPERATIONAL CRITERIA FOR THICKENING
OF BIOLOGICAL SLUDGES - UNIT 9A

APPENDIX 9A

OBJECTIVES

At the conclusion of this presentation, the participant shall be able to:

- Implement the batch settling flux system to the clarification and thickening processes, utilizing appropriate background and theoretical consideration selecting appropriate apparatus for performing each system.
- Identify the basis of aerator design with respect to solids residence time.
- Identify the basis of clarification design with respect to the constraints of overflow rate and the data developed by Pflanz and Agnew.
- Analyze the effect of increased and decreased hydraulic flow rates on thickening with and without control measures.
- Analyze the effects of flow proportional control and clarifier/ thickner performance.
- Analyze the effects of concentrated MLSS with no overload, minor overload, major overload, and high recirculation rates on the control of clarification.
- Analyze the change in sludge settling characteristics and identify methods of control.
- Analyze the effects of solids residence time on thickening characteristics and identify control measures.

DESIGN AND OPERATIONAL CRITERIA FOR THICKENING
OF BIOLOGICAL SLUDGES - UNIT 9A

APPENDIX 9A

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13	ISV and Settling Flux vs. Concentration	-22
19	Overflow Rate Design Constraints	-32

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Tables

(none)

Unit of Instruction 9A
Unit Process Design-Secondary Sedimentation
Appendix 9A
Design and Operational Criteria for Thickening of Beiological Sludges

Lesson Outline	Illustrations/Key Points
I. Background and Theoretical Considerations	
A. Thickening of Biological Sludges	
1. Activated sludge system.	Figure 1, Slide 7/2 Schematic of Activated Sludge System
Circulation rates and MLSS = Co	
B. Bic-Solids Sedimentation	
1. Sedimentation	
a. Velocity Components b. Flux Components	Figure 2, Slide 7/3 Cross-Section of Secondary Clarifier
2. Flux solids transport Components	
a. Settling Flux b. Bulk Flux c. Total Flux	Figure 3, Slide 7/6 Settling and Bulk Flux Solids Transport Components
C. Batch Settling Flux Approach	Figure 4, Slide 7/7 Total Flux Curve for Sedimentation
1. Geometric Technique	Figure 5, Slide 7/8
a. Under Flow Gradient, - u b. Settling Velocity, v	Batch Settling Flux Analytical Method
2. Comparison of Techniques	Figure 6, Slide 7/9 Batch and Total Settling Flux Curves
D. Solids Concentration Profile	
1. Construction of the Operating Line	
a. Y Intercept = $Co(Q + R)/A$ $-u = R/A$ b. X Intercept = Cu	
2. Illustrative Operating Lines Case A, Critical Loading	Figure 7, Slide 7/11 Clarifier Analysis for Three Loading Cases

Lesson Outline	Illustrations/Key Points
3. Underloaded Clarifier Case B	Figure 7, Slide 7/11
4. Overloaded Clarifier Case C	Figure 7, Slide 7/11
5. Concentration Profile	Figure 8, Slide 7/12 Solids Concentration Profiles
E. State Point Concept	
1. Definition Interception of Operating Lines	
2. Re-cycle Rate Operating Line	Figure 9, Slide 7/14 Batch Settling Flux Curve With Operating Lines and State Point
3. Over Flow Rate Operating Line $Q \approx Q - W$	
4. State Point	
a. Go = (Co x Q)/A b. Co = MLSS May not exist in clarifier.	Figure 9, Slide 7/14
5. Changes in Recyle Rate	
a. Recyle Rate Variations b. Overloading Recyle Rate	Figure 10, Slide 7/17 Batch Settling Flux Curve With Four Recyle Rate Operating Lines
6. Changes in Influent Flow Rates	
a. Diurnal Changes b. Overloading Influent Rate	Figure 11, Slide 7/19 Batch Settling Flux Curve With Three Over Flow Rate Operating Lines
II. Systems Design	
A. Interaction Between Aeration Basin and Clarifiers	
B. Design Basis/Aerator	
1. Solids residence time (θ_c)	
a. Determined by: soluble carbonaceous material; particulate carbonaceous material, thickening characteristics of the biological solids, nutrient control, and process stability.	

Lesson Outline	Illustrations/Key Points

b. Selection of SRT (θ_c)
Soluble effluent BOD, as shown in Figure 16 in the manual decreases rapidly with θ_c up to two days and then levels off. Figures 17 and 18 not applicable to municipal wastes.

c. Reactor design parameters.

$$C_o = \frac{Y(S_o - S)}{k + k_d\theta_c} \times \frac{\theta_c}{\theta}$$

Where Y and k are microbial characteristics and S the influent conditions. Inverse relationship between C_o and θ, the hydraulic residence time.

2. Hydraulic Residence Time, θ

a. Constraints

Lower Level - shock load response, kinetics of large molecules, maximum aeration capacity, maximum agitation, process stability.

b. Physical Constraint - maximum number of aerators per unit volume.
Biological Constraint - excessive agitation breaks up flux decreasing quality of the effluent.

c. Mobile Ciliates - low ciliates (desirable), favored by long θ_c but short θ.

C. Design Basis/Clarifier

1. $A = (C_o \times Q)/G_o$
(Other equations are not as useful in the state point analysis.)

2. Sizing the Clarifier:
From θ to MLSS(c_o), to G_o, to state point. Recycle rate can then be calculated.

Figure 9, Slide 7/14

Lesson Outline	Illustrations/Key Points
3. Trade off between clarifier size and recyle pumping. The greater G_o, the smaller A but greater recycle flow.	Figure 9, Slide 7/14
4. Clarification Constraint	
a. Define peak over flow rate equal to (Q - W)/A or effectively Q/A.	
b. Over flow restraints. Technically feasible - lie within lines.	Figure 19, Slide 7/32 Over Flow Rate Design Constraints
c&d. Clarification efficiencies While curves are in disagreement they do indicate the dependence of effluent quality upon the over flow rate.	Figure 20, Slide 7/33 Over Flow Rate Design After Pflanz Figure 21, Slide 7/34 Over Flow Rate Design Constraints After Agnew
5. Clarifier Under Flow Concentration Constraint	
a. Lower bound on wasted sludge solids (C_u). Needed when no additional thickening is done before sludge processing or for direct discharge to sand drying beds.	
b. Minimum under flow concentration constraints - Three different C_u	Figure 22, Slide 7/36 Under Flow Concentration Design Constraints
c. Design state point and construction feasibility limits.	
d. Maximum under flow concentration constraints - compressive strength may preclude high concentration. Not generally a design factor but should be checked.	
6. Recycle Rate Constraint	
a. Sometimes a least cost solution appears to have high recycle rates, however increased pumping costs and decreased effluent quality. Should study recycle rate constraints.	

Lesson Outline	Illustrations/Key Points
b. Two recycle rate constraints - upper bound for the feasible design domain.	Figure 23, Slide 7/38 Recycle Flow Rate Design Constraints
7. Application of Clarifier Constraints	
a. Clarification (over flow rate) only - shady area only is feasible.	Figure 24, Slide 7/39 Feasible Design Domain With Clarification Constraints Only
b. Clarification and recyle constraints.	Figure 25, Slide 7/40 Feasible Design Domain With Clarification and Recycle Rate Constraints
c. Clarification and under flow constraints	Figure 26, Slide 7/41 Feasible Design Domain With Clarification and Under Flow Concentration Constraints
d. Clarification, recycle and under flow constraints.	Figure 27, Slide 7/42

UNIT PROCESS DESIGN - DISINFECTION

UNIT 10

UNIT PROCESS DESIGN - DISINFECTION - UNIT 10

INSTRUCTORS LESSON PLAN

Unit Title: Unit Process Design - Disinfection

Instructional Goal: To develop in the student an awareness of operational considerations in the design of disinfection facilities.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures and table
Slides
Unit Objectives

General Plan of Instruction

- Review general theory of disinfection
- Show by examples operational features of disinfection facilities

UNIT PROCESS DESIGN - DISINFECTION - UNIT 10

OBJECTIVES

At the conclusion of this presentation, the participant should be able to:

- Identify the reasons for the use of disinfection techniques.
- List four ways in which disinfection techniques are thought to kill microorganisms.
- Utilize the formula for disinfectant kill including varying concentrations.
- Identify three disinfectants in use in the United States.
- List at least six absolute design considerations relative to disinfectants.
- Describe acceptable chlorine tank monitoring methods.
- Design safe, efficient, effective chlorine enclosures.
- Discuss methods to insure that fluid control systems are designed for operability.
- Discuss design methods to enhance safe movement of disinfectants in the facility.
- Define purpose of injectors and give one "design hint."
- Discuss the mixture of gases and wastewater.
- State the reason for residual control.
- Discuss the importance of adequate detention time and identify at least three means of providing good contact.
- Identify an acceptable drainage plan for disinfection facilities.

UNIT PROCESS DESIGN - DISINFECTION - UNIT 10

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Figure		
10.1	Sodium hydroxide safety system	
10.2	Feedback control system for chlorine injection	
10.3	Chlorine contact chamber with critical depth	-176
10.4	Location for chlorine residual sampler	-177
	Shed for devices for checking chlorine residuals and turbidity of final effluent	-178
10.5	Channel provides ample contact time	-182
	View of long contact chamber for pre-chlorination	-183
	View of long contact chamber for pre-chlorination	-184
10.6	Baffles to prevent short circuiting	-186

Instructors Presentation Guide

Unit of Instruction 10
Unit Process Design - Disinfection

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Removal or destruction of pathogenic organisms is not a major consideration in primary and secondary treatment processes.	
B. Major mechanism by which microbes are removed during primary and secondary treatment is settling of organisms associated with solids.	
C. Pathogenic microorganisms not associated with sewage solids or incorporated into secondary sludge flocs are discharged in the final effluent.	
D. Disinfection is required to produce a final effluent that is low in pathogenic micro-organisms.	
E. Disinfection is usually the final step in the treatment train.	
II. Effects of Disinfectants	
A. Disinfectants are thought to cause death of microorganisms in four ways:	
1. Damage to cell wall causing cell lysis* and death,	* Cell wall breakage causing "spillage" of interior of cell.
2. Alteration of cell membrane permeability allowing nutrients to escape,	
3. Changing colloidal nature of cell contents resulting in death, and	
4. Inhibiting enzyme activity thus preventing synthesis of vital products which alters critical cellular activity.	

Lesson Outline	Illustrations/Key Points
III. Dosage Considerations	
A. For a given concentration of disinfectant, the longer the contact time, the greater the kill.	
1. $N = Noe^{-kt}$ Where:	
K = first order rate constant	
t = time	
N_o = Number of organisms at time 0	
N = Number of organisms at time t	
2. The Kinetic expression applies only for a single disinfectant dosage.	
3. Varying disinfectant concentrations can be accounted for by using the following empirical constant:	
$C^n t = Constant$	
Where: C = Concentration of disinfectant; t = Time required for a specified % reduction.; n = A constant, which is based on characteristics of the disinfectant used.	
4. Several factors influence the rate of disinfection including:	Slide 1-24: Factors affecting rate of disinfection.
a. Number of organisms present in the wastewater,	
b. Type and concentration of disinfectant,	
c. Contact time provided between the organisms and the disinfecting agent, and	
d. Increasing temperature which results in a more rapid kill.	
5. Nature and condition of the target species influences disinfectant effectiveness.	
a. Growing cells are easier to kill than spores.	

Lesson Outline	Illustrations/Key Points
b. E. coli is more resistant to disinfectants than certain Salmonella species.	
6. Nature of suspending medium influences the effectiveness of disinfection.	Slide 1-25: Design consideration for disinfection.
a. Turbidity can cause disinfecting agents to be absorbed by particles in suspension.	
b. Can shield microorganisms by entrapping them.	
IV. Types of Disinfectants	Slide 6-169: Comparison of common methods of disinfection. See Table 10.1
A. Chlorine is the the most widely used:	
1. Efficient	
2. Relatively non-toxic to higher organisms in the concentrations used.	
3. Relatively inexpensive.	
B. Other halogens such as iodine are more efficient than chlorine but are more expensive.	
C. Ozone is used in the United States, as well.	
1. Used with teritary effluents primarily	
2. Has been used with secondary effluents but usually with chlorine backup since ozone production is energy intensive (thus high in cost)	
a. The future of ozone depends on energy costs.	
V. Absolute Design Considerations	
A. Must consider effectiveness of selection	
B. Must consider availability of selection	
C. Must consider required dose range	
D. Must consider safety aspects of alternatives	
E. Need for dechlorination must be considered when chlorine is utilized.	
F. Carefully design the method of addition	

Lesson Outline	Illustrations/Key Points
G. Accurate metering of the disinfectant is required to assure that desired dosage is being applied.	
H. Contact tank should be designed to preclude short circuiting	
1. Short-circuiting greatly reduces disinfection effectiveness.	
VI. Storage	
A. Should design with ease of storing and handling as desirable goal.	Slide 6-i72:Monorail System for chlorine handling facility. See Figure 10:1
B. Bulk chemicals must be alotted ample space/ storage near the chlorination building.	
1. Provide for truck access	
2. Provide for efficient transfer of chemicals	
C. When one-ton cylinders of chlorine are being handled provide sodium hydroxide safety equipment.	Figure 10.1 - Sodium hydroxide safety system is also needed.
VII. Chlorine Tank Monitoring	
A. Two scales, one of the indicating and one of the recording type are recommended for weighing cylinders in use.	
1. Use the scales to weigh on-line cylinders continuously so that operating continuity is assured.	
2. Each scale should be sized properly to deliver the chlorine at the maximum feed rate from the maximum number of cylinder required.	
3. Must provide substantial means for supporting cylinders on the scales.	
4. Construct scales of corrosion resistant material.	
5. Provide separate manifolds for the bank of cylinders on the scales.	

Lesson Outline	Illustrations/Key Points

a. Valve the manifolds so that one bank of cylinders may be replaced while chlorine is being withdrawn from the other bank.

6. Change of withdrawal from one bank to the other should be automatic when the "on-line" bank becomes empty.

7. In smaller plants a small cylinder of chlorine may serve as back-up while the large cylinders are being changed-out.

VIII. Design of Enclosures

A. Provide minimum enclosure if weather conditions permit.

B. Isolate gaseous chlorine and chlorination equipment rooms from other sections of the chlorine building by gas tight connections.

C. All doors and rooms containing gas chlorination equipment, and/or used for chlorine gas storage should open only to the outside of the building

D. Multiple exits should be provided for each room where chlorine gas is stored or used.

E. Floor drains from chlorine rooms should not be connected to floor drains from other rooms.

F. Chlorination storage containers and equipment should never be allowed to get below 60 degrees F.

1. Radiant heat is a desirable feature to include in open enclosures.

G. Provide chlorine handling enclosures with floor level, high capacity, powered exhaust, and gravity supply ventilation.

H. Forced mechanical ventilation should provide one complete air change per minute (60/hour) when the room is occupied, and one air change each three minutes (20/hour) when the room is unoccupied.

I. Air exhaust from chlorine rooms should be near the floor.

1. Point of discharge should be located judiciously to avoid contamination of air inlet to other buildings or inhabited areas.

Lesson Outline	Illustrations/Key Points
IX. Feed Control Systems	
A. Simplest types are:	
1. A manual controller which sets feed rate by hand adjustment, or	
2. A timer which varies chlorine injection rate depending on pre-set formula (ie. desirable time of day to raise or lower injection quantity).	
B. Injection rate can be controlled by monitoring effluent flow with a meter and adjusting accordingly.	Figure 10.2 - Feedback control system for chlorine injection
C. A residual controller bases disinfectant feed rate upon the chlorine residual downstream from the point of injection.	
1. System is fairly complex.	
2. Wastes little chlorine in the feeding/control process.	
D. Most complicated system bases chlorine feed rate on a combination of wastewater flow and chlorine residual.	
1. Most economical from a chemical use viewpoint.	
XI. Movement of Disinfectant in Facility	
A. The mode of disinfectant transport within the facility depends upon:	
1. the quantity of disinfectant being moved, and	
2. the distance over which it must traverse..	
a. Generally, pressure is used to move small quantities of chlorine gas from cylinders to chemical feed equipment.	
(1) Heavy black iron piping is required.	
(2) Local freezing of piping may occur if chlorine is transported in iron piping.	

Lesson Outline	Illustrations/Key Points

(3) Gas must be clean and dry if it is transported in iron piping.

b. Safety considerations restrict the distance over which the gas can be moved.

c. Chlorine gas under vacuum is becoming more used.

(1) Inherent safety of transport.

(2) Rapid control response over long distances.

(3) Has been used successfully in distances up to 10,000 feet.

(4) Fiberglass or PVC piping is required as conduit.

d. Water solution is the most common method over relatively short distances.

(1) Rubber, saran lined, or PVC pipe can be used.

B. Transport over very long distances is impractical.

1. Because of high friction losses.

2. Because of lengthy delays in response time.

XII. Injectors

A. Injectors can be used to get the disinfectant into the wastewater stream.

B. Chlorine injectors which use water pressure should be separated from the remainder of the water system.

1. Because the injectors may not work well when high pressure water is being used for other purposes (such as cleaning sedimentation tanks).

XIII. Mixing

A. It is important that mixing of chlorine be rapid and thorough.

Lesson Outline	Illustrations/Key Points
B. Reaction must be completed quickly to maximize disinfection.	
C. Mechanical mixing is an option.	
1. Pumps	
2. Propellors	
3. Turbines	
D. Mechanical mixers should operate under confined conditions to assure maximum mixing.	
E. Head losses at the downstream control gates on secondary effluent channels may provide sufficient energy for mixing of disinfectant and wastewater.	Slide 6-176: Downstream control gates on secondary effluent channel being used for chlorine mixing. See Figure 10.3
1. Flow should pass through critical depth to achieve maximum agitation.	
XIV. Residual Control	Slide 6-177: Chlorine residual sample taken downstream of the mixing point. This residual can be used to control the rate of chlorine injection. See Figure 10.4
A. Take effluent sample downstream from point of mixing if residual control is utilized.	
B. Downstream sample can be used as a final check on the quality of the secondary effluent.	Slide 6-178: Shed containing devices for checking chlorine residuals and tubidity of final effluent.
1. Accomplished by installing an automatic recording turbidimeter in the same line that is used for checking chlorine residual.	
XV. Detention Time	
A. Must have sufficient detention time of chlorinated wastewater to assure maximal destruction of pathogenic organisms.	Slide 6-182: Long contact channe used for pre-chlorination. See Figure 10.5.
1. Chlorine contact chambers have been designed to serve this function.	Slides 6-183, 6-184: Views of long contact chamber used for prechlorination.
2. Dual chambers should be constructed to provide reliability of operation, and redundancy when one unit is removed from service for cleaning or maintenance.	
3. Ideal contact chamber is a pipeline.	
a. Dechlorination becomes difficult using a pipeline.	

Lesson Outline	Illustrations/Key Points
4. An open chamber/channel with many baffles, to prevent short-circuiting, is used in many facilities.	Slide 6-186: Baffled chlorine contact chambers. See Figure 10.6.
XVI. Solids Removal and Drainage	
A. Solids deposition in contact chambers can be lessened by continuous air agitation.	
B. Vacuum removal solids can be used.	
1. Advantage over air agitation in that a chamber need not be taken out of service.	
2. Disadvantage is that vacuum removal is more labor intensive than agitation.	
C. Drains should be included in contact chambers.	
1. Should be capable of emptying chambers completely and rapidly.	
2. Should discharge into the influent sewer to the plant.	

UNIT PROCESS DESIGN - EFFLUENT DISCHARGE

UNIT 11

UNIT PROCESS DESIGN - EFFLUENT DISCHARGE - UNIT 11

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Effluent Discharge

Instructional Goal: To develop in the student an awareness of operational considerations in the design of disinfection works.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Show by examples operational features of effluent discharge works.

UNIT PROCESS DESIGN - EFFLUENT DISCHARGE - UNIT 11

OBJECTIVES

At the conclusion of this presentation, the participant should be able to:

- State the three principal means used to measure effluent flow.
- Identify at least three means of improving discharge effluent.
- Discuss the requirements relative to facility elevation.
- Design efficient diffusion systems.

UNIT PROCESS DESIGN - EFFLUENT DISCHARGE - UNIT 11

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11.1	Effluent measurement weir	163-6-188-D
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	Effluent discharge, 6 inches Hg vacuum	-198
	Effluent discharge; 11 inches Hg vacuum	-197
11.2	Utilization of gravity or pump discharge and inflow	-192
	Effluent pumps	-194
11.3	Effluent diffuser	-195
11.4	Diffuser placement on river bottom	-196
11.5	Port distribtuion on diffuser	-220

Tables

(none)

Instructors Presentation Guide

Unit of Instruction 11
Unit Process Design - Effluent Discharge

Lesson Outline	Illustrations/Key Points
I. Effluent Flow Measurement	
A. Three principal means are used to measure effluent flow.	
1. Flumes - can be used when discharge is into a body of water that does not fluctuate in elevation (such as a stable lake).	
2. Weirs -	Slide 6-188: Effluent weir design drawing.
a. Inexpensive and easy to install.	See Figure 11.1
b. Often used at smaller facilities and package plants.	
c. Adaptable to changes in plant flow.	
(1) Can be enlarged or changed out as plant flow expands.	
3. Orifices or pipe meters	
a. Require full outfalls under all plant flow conditions.	
II. Discharge Techniques	
A. Type of discharge technique depends on locational constraints.	
B. Where discharge is into a water body at a significantly lower elevation than the treatment facilities foaming may be a problem.	
1. Placing the outfall pipe below the water body surface will prevent the formation of foam.	

Lesson Outline	Illustrations/Key Points
2. Foam can also be alleviated by placing the outfall pipe or channel on a slope of no more than 15 degrees from horizontal.	
C. Maintenance of a vacuum in the outfall pipe will prevent freefall of the effluent reducing the amount of entrained air, thus reducing foaming at the discharge point.	Slides 6-200,6-199,6-198 and 6-197: Series showing foam reduction at outfall when a vacuum is maintained in the outfall pipe.
III. Elevation of Facility	
A. Facility should be located high enough to provide adequate flood, tidal or storm wave protection.	
B. Discharge structures should be designed so that gravity flow is used under average flow conditions.	Slide 6-192: Section at Seattle plant showing how gravity flow is used for effluent discharge into Puget Sound except at high tide conditions.
1. If a facility is situated at a high elevation to insure gravity discharge at flood stages, then the influent pumps will be providing excessive head under normal flow conditions.	See Figure 11.2
2. This results in the need for larger pumps and greater energy requirements over what would be needed if the plant were at a lower elevation.	
3. When flood stage is above normal, discharge level effluent pumps can be used to overcome the head insuring continued outfall of treated wastewater.	Slide 6-194: Effluent pumps.
IV. Discharge Diffusion	
A. A diffuser can be located at the end of an outfall pipe to mix the wastewater with the ambient water.	Slide 6-195: Effluent discharge into a receiving stream using a diffuser pipe.
1. Outfall pipe should transport the effluent to a point in the receiving water where mixing can occur (such as center of stream.) A diffuser can be located here.	See Figure 11.3
B. Diffusers use the momentum of the wastewater flow and the density differences between the effluent and the receiving water to enhance mixing.	

Lesson Outline	Illustrations/Key Points
C. Locate a diffuser along a stream bottom using horizontal jets to take full advantage of density differences and effluent momentum.	Slide 6-196: Diffuser located along a river bottom with jets discharging horizontally into the direction of river flow.
D. Flow rate out of individual ports should be uniform along the entire length of the diffuser to maximize mixing.	See Figure 11.4
1. Can be done by making ports near the entrance smaller than those near the end.	
E. Flow velocities in all parts of a diffuser should be 2 to 3 fps at peak flow to prevent deposition of solids and ambient water intrusion into the pipe.	Slide 6-220: River diffuser with horizontal discharge jets and pipe diameter reduction to maintain constant velocity.
1. May be achieved by reducing size of pipe as distance from entrance increases.	See Figure 11.5
F. Discharge velocity out of the ports should be greater than the internal flow velocity inside the diffuser	
1. The sum of all port areas downstream of any point in the diffuser must be less than the diffuser pipe area.	
2. In general, the sum of all diffuser port areas should not be greater than ½ to 1/3 the pipe area in that location.	
G. Outlet ports should be simple with no protruding objects to entrain debris.	
H. If nozzles are used they should be easily replaceable.	
I. Inside of all ports should be bell mouthed to prevent clogging.	
J. Where ports are placed on both sides of a pipe they should be staggered to prevent flow instabilities and/or oscillations.	
K. A flap gate located at the end of the diffuser pipe will make maintenance of the system easier.	

UNIT PROCESS DESIGN - SLUDGE TREATMENT

UNIT 12

UNIT PROCESS DESIGN - SLUDGE TREATMENT - UNIT 12

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Sludge Treatment

Instructional Goal: To develop in the student an awareness of operational considerations in the design of sludge treatment facilities.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Viewgraphs of figures
Slides
Unit Objectives

General Plan of Instruction:

- Review general design considerations for sludge treatment facilities.
- Show by examples operational features of sludge treatment facilities.

UNIT PROCESS DESIGN - SLUDGE TREATMENT - UNIT 12

OBJECTIVES

At the conclusion of this presentation, the participant should be able to:

- Define primary and secondary sludges.
- Define appropriate sludge piping.
- Identify appropriate sludge system instrumentation.
- Discuss efficient means for sludge thickening and dewatering.
- Identify and discuss various designs which enhance dissolved air floatation.
- Discuss centrifugal thickening and identify numerous "design hints."
- List and discuss various sludge stabilization techniques and efficient system designs.
- Discuss vacuum filtration as a design option.
- Design floating covers.
- Identify three types of heat exchanger options and heating engines.
- Discuss sludge filling and withdrawal.
- List three "design hints" to enhance gas production and utilization control.
- Design an effective aerobic digestion system that utilizes "design hints."
- Identify critical areas in sludge conveyance design and various options to enhance operation.

UNIT PROCESS DESIGN - SLUDGE TREATMENT - UNIT 12

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Instructors Presentation Guide

Unit of Instruction 12
Unit Process Design - Sludge Treatment

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Disposal of screenings, grit and sludge are a challenge for the design engineer.	
B. These solids contain all the components of raw sewage.	
1. Primary sludge - putresible organic solids.	
2. Secondary sludge	
a. Soluble organic material bond in sewage converted into microbial biomass.	
b. Toxic compounds	
c. Pathogens	
C. Large volume of secondary sludge generated at sewage treatment plants (an average of 19,400 gallons/million gallons of sewage)	
D. Sludge handling facilities are often deficient in design or their operation is poorly understood by plant personnel.	
II. Piping and Instrumentation	Slides 11-12 through 11-24: illustrate sludge pumping and piping systems and may be used throughout by the instructor.
A. Piping	
1. The piping system should have isolation valves to allow for equipment or metering repairs.	Slide 11-21: Valves should be provided to permit isolation of pumps from the sludge stream.
2. Provisions should be made for cleaning, draining and flushing the piping.	Slide 11-30: Cleanout at elbow below the waste studge hopper.
a. Flanged tees and crosses	
b. Cleanouts	

Lesson Outline	Illustrations/Key Points
2. Four methods are used to thicken and dewater sludges. a. Gravitational thickening b. Dissolved air flotation c. Centrifugal thickening d. Vacuum filtration	
3. Discussion will center on design characteristics that affect the operation and maintenance of sludge thickening devices.	
B. Gravitational thickening	
1. Tank shape can be either circular or rectangular.	
a. Circular advantages	
(1) Sludge delivered continuously to the point of drawoff.	
(2) Easy to maintain a substantial sludge depth and to avoid ratholing in the area of sludge withdrawal.	
b. Rectangular advantages	
(1) Utilize less area than circular tanks.	
(2) Sludge withdrawal pumps can be located closer to rectangular tanks which help alleviate pipe clogging.	
c. Sludge collection	
(1) Mechanical collector arms in circular tanks.	
(2) Travelling flights in rectangular tanks.	
(3) Circular tanks should have steep bottom slope (1.5 to 3.0 inches/foot) to enhance movement of solids into withdrawal zone,	

Lesson Outline	Illustrations/Key Points

3. Provisions for backflushing with positive displacement pump discharge is desirable.

4. Hot water, steam injection or chemical cleaners should be available for degreasing long lines containing raw sludge or scum.

5. Frozen sludge can be removed from pipes using compressed air.

6. Sludge grinders may be considered if downstream processes are susceptible to trash or rag build-up.

B. Instrumentation

1. Accurate and reliable monitoring of sludge streams is more difficult than monitoring and controlling wastewater streams.

2. Frequent maintenance and calibration is essential.

3. Redundancy of sensors may be necessary to obtain reliable readings.

4. Sludge meters should be installed to insure that the section of piping containing the sensor has full pipe flow.

5. Pressure gauges with non-clog diaphragms should be used to avoid errors due to sludge deposition.

6. Thermocouples should not be located in stagnant zones of tanks and pipelines.

7. Turbidity may be used to monitor supernatant and recycle streams as a warning to significant solids losses.

III. Sludge Thickening and Dewatering

A. Introduction

1. Purpose of thickening and dewatering is to reduce the volume of waste-sludge,

Lesson Outline	Illustrations/Key Points

prevent dilute underflow concentrations and reduce sludge residence time in the thickener.

In rectangular tanks there should be lateral or transverse movement of solids to the withdrawal point and the hopper must be deep enough to ensure rat-holing doesn't occur. Sludge collection machinery should be strong enough to handle the added load derived from the necessity for heaping sludge in the vicinity of the point of withdrawal.

2. Design considerations

   a. If combined thickening is used, the WAS line should be relatively long and the primary sludge line short. These are then combined into a common thickener feed line.

   b. Design of thickener feed mechanism should minimize turbulence in the feedwells.

      1b. Bottom feed inlets promote low turbulence by promoting vertical, then lateral flow of feed sludge.

      2b. Tangential entries or opposing tangential feed entries are preferred over feed directed vertically downward.

      3b. Horizontal feed entry located just under the surface of the liquid and directed toward the center of the thickener feedwell is satisfactory.

   c. Sufficient torque must be designed into the rakes and drive mechanism to overcome drag and sludge accumulation.

      (1) The rated torque should be high enough to provide sufficient driving force. Continuous operation at torques greater than 40 to 50% of the rated capacity of the mechanism will greatly shorten its life.

Lesson Outline	Illustrations/Key Points
d. Separate scum treatment is suggested as this material may accumulate in the feedwell if pumped to gravity thickener. (1) Scum should be sent to adjacent tank, overflow sent to final disposal, underflow recycled back to primary or secondary treatment. e. Continuous withdrawal of sludge is preferred. If intermittent withdrawal is practiced sludge pumps should be run for short intervals on a frequent basis rather than for longer periods once or twice a shift . f. Sludge pumps (1) Preferred are plunger-type positive displacement with double inlet valves (2) Progressing cavity pumps can also be used if they are preceeded by degritting equipment to prevent wear. (3) Multiple pumps or variable speed pumps are desirable to allow for controlled removal. g. Sludge lines (1) Minimize distance between discharge cone and inlet of pump. (2) Piping should be provided with adequate access points for clean-out. (3) Access to piping must be considered when it is designed. A piping gallery may be necessary. (4) Dual sludge lines are suggested if plugging is anticipated. (5) The underflow pump should be beneath the liquid level in the thickener to insure that the suction remains flooded.	

Lesson Outline	Illustrations/Key Points
h. A means for determining sludge blanket level and the ability to sample and monitor solids concentrations in the supernated stream should be included.	
i. Location considerations	
(1) May be located within a cluster of clarifiers for convenience.	
(2) If grit removal is carried out in the thickener, the grit handling facilities should be located at the thickener site.	
(3) Access for tank trucks should be provided in case the dewatering equipment is out of service.	
(4) Thickeners should be located where they receive frequent maintenance but far enough from plant boundaries to keep them from casual observation.	
C. Dissolved Air Flotation	
1. Introduction	
a. DAF uses fine bubbles to buoy up sludge solids and raise them to the liquid surface where they are removed by mechanical means.	Slide 1-13: Table of DAF applications.
b. Heavier solids settle to the bottom where they are removed by mechanical means,	
c. Supernatant is recycled back through the treatment plant	
2. Methods of dissolved air flotation	Slide 1-14: Modifications of DAF.
a. Diffused or induced air flotation: air pressure and turbulence is used to shear the air in the sludge.	
b. Dissolved air flotation may use either pressure or vacuum to dissolve and release air from solution.	
(1) In vacuum flotation, the liquid is saturated at atmospheric pressure and released by vacuum.	

Lesson Outline	Illustrations/Key Points
(2) Pressurized flotation uses several atmospheres of pressure to increase the amount of air that can be released upon pressure let-down.	
c. Contacting patterns in pressurized DAF.	
(1) Direct pressurization: entire flow pressurized to allow large amounts of air input the major disadvantage is that solids and floc particles are subjected to shear forces during pressure release.	Slide 1-15: Direct pressurization DAF schematic
(2) Split treatment: a portion of flow is pressurized and subjected to shear forces during pressure release. Limits the amount of air which can be put into wastewater.	Slide 1-16: Split treatment DAF
(3) Pressurized recycle DAF: minimize shearing of flocs and solids by pressurizing a portion of the recycle.	Slide 1-17: Pressurized recycle DAF. Figure 12.1: Plan view of circular DAF tank indicating center feed and the use of saturated recycle. See
3. Design considerations for DAF	
4. Operational considerations	
a. Rectangular tanks are preferred at treatment plants where space is at a premium. Circular tanks can be built to handle larger hydraulic loads.	
b. DAF thickeners have greater thickening capacity than gravity units and equivalent amount of thickening capacity can be built in much smaller space using DAF. Thus DAF units can often be placed in buildings.	Slide 6-164: Four circular DAF thickeners used at a regional treatment facility. See Figure 12.2
C. Skimmers: used to remove the solid/gas matrix from the surface and maintain a constant blanket depth.	Slide 6-166: Section of circular DAF. Use for discussion of DAF to follow.
(1) Use automatic timers to keep float blanket 12 to 18 inches deep.	See Figure 12.3

Lesson Outline	Illustrations/Key Points
(2) The skimmers should have variable speed of up to 25 ft/min. for flexibility in operation.	
(3) A convenient way to adjust the depth of the skimmers will enable the operator to optimize float thickness.	
d. Floor rakes for removing settled solids should be able to be operated independently of the skimmer.	
e. The overflow weir regulates the capacity of the DAF unit and should be adjustable.	
(1) Overflow rates from 1.0 to 0.4 gal/ft. 2/day are used.	
(2) With constant air: solids ratio performance increases with decreasing overflow rate.	
(3) Retention times range from 10 to 60 minutes. Performance improves with increasing retention.	
f. Air: Solids ratio - a measure of the amount of air applied per unit mass of solids in the wastewater.	Slide 1-18: Air: Solids ratio
(1) Optimum ratio is best determined from laboratory or pilot tests.	
(2) A:S is a function of recycle flow rate, operating pressure, and efficiency of saturation drum	
(3) Flexibility in recycle flow rate and pressure enables the operator to adjust to changes in influent wastewater or sludge.	
(4) Should have flexibility to use plant secondary effluent dissolution if DAF overflow becomes overloaded with solids.	
g. Recycle should be injected into sludge stream prior to that stream entering the flotation tank.	Slide 6-167: Tank for pressurizing recycle.

Lesson Outline	Illustrations/Key Points

(1) Air impregnated sludge should be brought into the tank at the liquid surface to prevent agitation that might disturb the bottom sludge layer.

(2) Specific gravity of the float should be between 0.6 and 0.7 to keep the material floating and increase the solids content of the mat.

(3) Pressurization tank should be located adjacent to DAF tank and pressurization pump to minimize pumping requirements and head loss. Tank should be equipped with steel legs, a drainage opening, an access manhole, a liquid level sight glass, a pressure gauge and preasure safety release valve.

h. Other Provisions

(1) Accurate flow splitting for multiple flotation units.

(2) A method for determining float concentration.

(3) A means for effluent stream solids load that is recycled to the head of the plant.

(4) Variable flow rate control of the pressurized recycle and influent stream.

(5) Variable air pressure control.

(6) Effective moisture removal on instrument air system if pneumatic controls are used.

D. Centrifugal thickening

1. Introduction

a. Centrifugation uses centrifugal force of 500 to 3,000 times that of gravity to thicken sludge.

Lesson Outline	Illustrations/Key Points
b. Have high capacity and low space requirements when compared with gravity thickeners.	
c. Three types of centrifuges are used to process waste sludge.	
(1) Imperforate basket	
(2) Disk-nozzle	
(3) Solid-bowl conveyor	
2. Centrifugation requirements.	
a. Wastewater treatment plants normally require one standby centrifuge in a small installation and approximately 25% standby capacity in large installations.	
(1) Ideally, centrifuges should be sized such that 2 or 3 can handle the projected load.	
(2) Imperforate basket centrifuges are found most often in smaller plants requiring from 2 to 6 units.	
b. Availability of sludge influences selection of the type of centrifuge needed.	
(1) If sludge is wasted intermittently conveyor or basket centrifuges are most appropriate since dish centrifuges need to be cleaned after shutdown to prevent sludge from drying in nozzles.	
(2) Imperforate basket centrifuges can handle most abrasive sludges with little wear relative to other centrifuges.	
3. Operational considerations	
a. Installation	
(1) Should be supported on piers or elevated concrete or steel platforms to allow free discharge of	

Lesson Outline	Illustrations/Key Points

thickened sludge and supernatent. Platforms should provide inertia loading support 2.0 times the equipment weight vertically and 1.5 times the weight horizontally.

(2) Feed piping and effluent connection should be flexible and cake chutes should not be rigidly fastened to receivers.

(3) Vibration isolators should be installed to dampen the transmission of vibrations from centrifuge to support structure.

(4) Centrifuges generally operate at noise levels of 80 to 90 dba. Sound reflecting surfaces should be covered with sound absorbing material. Operator stations should be isolated from centrifuge room.

(5) Overhead lifting and transport facilities for the rotating assembly of the centrifuge must be provided for maintenance. A monorail with a dual-chain hoist should be installed over the centerline of the machine.

(6) Drains, flush water connections and sampling taps should be strategically located in the piping entering and leaving the centrifuge. A blind tee at the entrance to the centrifuge feed pipe can be used for adding polymer, cleanout or sample tap.

b. Pumps

(1) Progressive cavity pumps are preferred for feed as they permit effective metering and control of the feed rate. The hydraulic capacity of processive cavity pumps is more nearly a function of pump speed than it is with centrifugal pumps.

Lesson Outline	Illustrations/Key Points
(2) Drives should permit at least a 5-fold pumping range to match variations in solids feed concentration to solids loading objectives.	
(3) Care should be taken to insure wet operation of progressing cavity pumps. Flow/pressure detectors for automatic on/off control should be incorporated into design.	
(4) Feed sludge should be removed from a wet well where feed is relatively uniform in consistency.	
(5) In multi-centrifuge installations, feed from a single pump may be adequate for secondary sludge. For combined sludges, with materials that may foul distribution valves, an individual pump with variable speed drive for each centrifuge is suggested.	
6) Feed control should not function until centrifuge is up to full speed. Should shut off if the centrifuge malfunctions.	
c. Polymers	
(1) Mixing and feeding system should be provided even if polymers are not planned for routine use.	
(2) Chemical conditioning equipment and chemical storage should be near the centrifuge station.	
(3) Fresh water should be used for polymer make-up and dilution.	
(4) Polymer wetting device can be difficult to maintan and be a safety hazard if device plugs and gets polymer on the floor. Attention should be paid by designers to reduce maintenance and prevent unsafe handling of these devices.	
(5) Use a reliable and accurate proportioning system to control polymer feed.	

Lesson Outline	Illustrations/Key Points
6c. Because polymer solutions can be very viscous long suction lines or high discharge heads should be avoided. Piping should be of stainless steel or PVC.	
7c. Capability to add chemical aids to the polymer will anticipate potentional problems such as scaling and foaming.	
8c. The point at which polymer is added can affect performance (eg. internally within the centrifuges, the feed pipe or at suction of feed pump). These should be considered when polymer piping is designed.	
d. Cycle time controlled by timing, clarity of centrate, or build-up of cake in bowl. Timer usually provided for feed cycle.	
e. Discharge	
1e. If discharge valve is used, the underflow line should have horizontal run of 10 feet or less before discharging into a sump.	
2e. Centrate is discharged by gravity back to headworks, secondary treatment or a centrate sump.	
E. Vacuum Filtration	Slides 11-33 through 11-36: Various vacuum filtration systems. May be used throughout the discussion by the instructor.
1. Sludge floc destruction must be minimized to achieve optimal filtration. Time variable speed agitators in filter tanks will maintain homogenous conditions but reduce floc destruction relative to continuous agitation.	
2. Feed Rate	
a. Sludge level in feed tank can be used to control feed rate onto the filter drum.	
b. Flow rate of sludge into feed tank can be used to control the coagulant feed rate once the ratio of sludge volume to coagulant volume is determined.	

Lesson Outline	Illustrations/Key Points
3. Filter media a. Seamless cloths are preferred as est holes in seamed cloths appear at the seams. b. Washing showers and trough should be designed for 10 gallons per minute of spray per foot of drum length. 4. Cake removal a. Flexible blades will compensate for drum trueness and deflections in the blade holder. b. Blow back air to billow the cloth near the sludge scrapper should be provided. 5. Form vacuum system should be separate from the drying vacuum system. This enables operator to maintain adequate form vacuum regardless of the conditions during the drying cycle.	
IV. Sludge Stabilization A. Introduction 1. Purpose: To reduce volume of sludge and alter it to a form that is more environmentally acceptable 2. Techniques a. Microbial (1) Anaerobic digestion (2) Aerobic digestion (3) Composting b. Thermal energy (1) Incineration (2) Heat drying.	
B. Anaerobic digestion 1. Theoretical considerations	Slide 1-45: Anaerobic digestion overview.

Lesson Outline	Illustrations/Key Points
a. It is a two step process that takes place in the absence of oxygen.	
(1) Hydrolysis and fermentation of complex organic compound to organic acids.	
(2) Conversion of organic acids to methane and carbon dioxide is the the rate limiting step.	
b. Factors affecting process performance.	Slide 1-46: Factors affecting digestion.
(1) Solids retention time of at least 10 days is necessary for development of gas formers.	
(2) Growth rate of methanogenic bacteria increases up to 100 degrees F.	
(3) PH range between 6.6 and 7.6 is optimal.	
(4) Mixing of digestor contents between organisms and substrate.	
2. Process modifications	Slide 1-47: Anaerobic digestion process modifications.
a. Conventional or standard rate: a single stage system with minimal mixing.	
b. High rate: a two stage system with first stage being mixed and the second serving as a separator.	
(1) Should include provisions to mix and heat secondary.	
(2) Should include provision to pump secondary digester sludge to secondary units for reseeding and extended sludge dention time.	
3. Design considerations	Slide 1-48: Design considerations for anaerobic digesters.
a. Activated sludge is difficult to digest and is not conducive to high rate digestion and larger digestion capacity is required for this sludge.	

Lesson Outline	Illustrations/Key Points
b. The concentration of volatile solids determines the length of time required for complete stabilization. A sludge with 80% VSS requires longer detention times for stabilization than a sludge with 70% VSS).	
c. Short circuiting is reduced with greater detention periods. With 10 day dention time, 10% of each days feed will be short circuited. With 30 days detention 3-1/3% will be short circuited.	
3. Operational Considerations	Slide 6-207 and 6-215: Floating covers.
a. Fixed and floating covers	Slide 11-47: Fixed covers.
(1) Floating covers permit sludge feed without concurrent withdrawal and do not develop gas leaks as easily as fixed covers.	
(2) Floating cover design.	Slide 6-212: Section of an anerobic digester with a floating cover Point out need for ballast on shirt freeboard and side clearance between cover and tank body. See Figure 12.4
(a) Require sufficient ballast around shirt to minimize gas/liquid interface and prevent cover unstability due to foaming.	
(b) Should include a 12 to 18" freeboard and 12 to 24" shirt.	
(c) Side clearance between cover and tank body of no more than 3"	
(d) Flexible hose should be used for lines entering cover.	Slides 6-209: Flexible hose on floating cover.
b. Mixing	Slide 6-208: Mobile catwalk for access onto floating cover.
(1) Alternatives	
(a) Mechanical: is difficult if floating covers are used, bearings and blades are also maintenance problems.	
(b) Sludge circulation: energy intensive.	

Lesson Outline	Illustrations/Key Points
(c) Digester gas: gas for this system should be independent of gas used for other purposes	Slides 11-64 through 69: Views of gas mixer and blower.
(d) All piping except the mixers should be placed up against the walls.	Slide 6-213: Plan of digester showing 4 separate gas type mixers Indicates that separate gas piping is used for mixers. See Figure 12.5
c. Heat exchangers.	Slide 6-217: All piping but gas mixers should be up against wall of digester. See Figure 12.6
(1) Internal heat exchangers have to be abandoned due to maintenance difficulties.	Slides 11-53 through 55: Sludge heat exchangers.
(2) Direct steam injection is noisy and subject to control failures which may excessively heat piping and digester covers.	Slide 6-216: Section of a concentric tube raw sludge heat exchange See Figure 12.7
(3) Spiral and concentric tube external heat exchangers are most efficient. Use insulation on all piping and tanks to reduce gas requirements for heating.	Slide 11-45 and 11-46: Heating energy can be conserved by burying anaerobic digesters.
d. Heating engines	Slide 6-201: Digester heating engines.
(1) Digesters using reclaimed heat should have standbyheating capabilities for periods when heating engines are down.	
(2) Liquid propane should be available for engines when digester gas is not available.	
(3) Hot water piping in engine rooms should be segregrated for quick detection of engine oil leakage into the water.	
(4) Individual boilers for each digester are preferred to a large single boiler tied to a manifold.	Slides 6-221 and 6-222: Digester boilers
e. Sludge feeding and withdrawal	Slide 11-48: Sludge pumps.
(1) Raw sludge should be mixed with circulated sludge from digester before feeding.	Slide 11-50: Sludge sampling area

Lesson Outline	Illustrations/Key Points
(2) Quarter point circulation with access to digester at 4 points around circumference in addition to top and bottom access is recommended.	Slide 6-218: Flexibility of quarter point circulation and center removal of sludge. See Figure 12.8
(3) Positive displacement pumps are preferred in order to have maximum control over pumping.	Slide 6-206: Positive displacemen pump for sludge pumping.
f. Gas production and utilization	Slide 11-71 and 11-72: Waste gas exhaust pipes.
(1) Should be monitored as a measure of digester function.	Slides 11-57 and 11-58: Gas processing equipment on cover of digester.
(2) Digester gas is 100% saturated with moisture. Cold exposed piping will condense this moisture, but sediment and moisture traps should be provided.	Slides 11-61 through 11-63: Gas processing equipment.
(3) Gas is used most efficiently in plant direct drive engines followed by use in boilers and on-site generation of electricity. Gas can be used without scrubbing if boiler and engine temperatures are kept above 200 degrees F.	Slide 6-203 & 202: Direct drive engines run off digester gas.
g. Cleaning and maintenance	Slide 6-223: Digester gas used for on-site generation of electricity.
(1) Access to interior should be provided as digester must be drained and cleaned.	Slide 11-73 and 11-74: Sludge stream from a digester being emptied for service.
(2) Should have large debris handling pump station for grit and debris.	Slide 6-212: Section of digester showing access manholes. See Figure 12.4
(3) Drain pipes should be at least 8" in diameter.	Slides 11-75 and 11-76: Access manholes.
C. Aerobic Digestion	Slide 6-212: Digester section showing drain pipe off base. See Figure 12.4
1. Introduction and theoretical considerations	Slide 6-219: Positive slope on drain pipe. Four digesters draining into a common sump. See Figure 12.9
a. Maintains microorganisms in enclogenous respiration to reduce sludge volume.	Slide 6-211: Drain system for a complex of 4 anaerobic digesters. See Figure 12.10
b. Advantages	Slide 11-77: View of aerobic digesters.

Lesson Outline	Illustrations/Key Points
(1) Volative solids reduction comparable to anaerobic digestion.	
(2) Lower BOD concentrations in the supernatent liquor.	
(3) Production of an odorless biologically stable end product.	
(4) Production of a sludge with excellent dewatering properties.	
(5) Recovery of the fertilizer value of sludge.	
(6) Fewer operational problems than anaerobic digestion.	
(7) Lower capital cost than anaerobic digestion.	
c. Aerobic digestion is energy intensive in oxygen requirements and does not produce a useful by-product such as methane.	
2. Operational Considerations	Slide 1-50: Design of aerobic digesters.
a. Detention time - 15 days for WAS, 20 days for primary sludge or combined primary sludge/WAS.	
b. Use of multiple tanks in series is recommended.	
c. Air supply	
(1) Enough mixing capability should be provided to permit at least 30cfm per 1,000 $ft.^3$ of tank volume with the largest blower out of service.	Slide 11-78, 79: Air Compressor for aerobic digester.
(2) Non-clog diffusers are recommended especially if freezing temperatures are expected.	Slide 11-89 through 11-92: Swing diffusers for aerobic digesters.
(3) Submerged turbine or floating surface mechanical permit liquid level variation.	Slide 11-80 through 11-88: Servicing air diffuser on an aerobic digester.
	Slide 11-93, 94, 95: sludge drying beds following aerobic digestion.

Lesson Outline	Illustrations/Key Points
D. Incineration and Heat Drying	Slide 11-101, 102 - Incinerator
1. Incineration considerations	
a. Include storage for combustible materials.	
b. Effective equipment for blending sludge cake with dry or organic material.	
c. Means of controlling sludge concentration.	
d. Suitable means for ash removal and disposal.	
2. Heat drying considerations	Slide 11-97: Screw dryer.
a. Accessibility to equipment	Slide 11-99, 100: Sludge conveyor and flasher dryer.
b. Temperature and moisture control	
c. After burners may be necessary to reduce particulate load in exhaust.	
E. Composting	Slide 11-103 through 11-109: Compositing operation.
1. Facilities should be well drained.	
2. Provide a reliable means of separating bulking agent from composted sludge.	
3. Ample room for maneuvering equipment and storage or raw and composted sludge is required.	
V. Sludge Conveyance Considerations	
A. Sludge properties of concern	Slides 11-7 and 11-8:
1. Dilute wastewater sludges have fluid properties similar to water (i.e. an incompressible and homogeneous newtonian fluid.)	Instructor define newtonian fluid and nonnewtonian fluid.
2. As sludge solids concentration and/or VSS concentration increases sludge fluid characteristics will behave as a nonnewtonian fluid (i.e. thickened sludges, some primary sludges and digested sludges.)	

Lesson Outline	Illustrations/Key Points
3. Other deviations from typical liquid behavior result from debris in sludge as well as from entrained gases.	
4. Deviations from normal sludges should be considered when designing conveyance facilities.	
B. Pumps	
1. Provide sufficient head capabilities for sludge with viscosities higher than water.	
2. Horsepower of motors should be capable so overloading is avoided when the sludge thins out and becomes less viscous.	
3. Easy clean-out should be provided.	
C. Pipes	
1. Should be large enough to pass rags and matted debris and to avoid excess friction loss on the suction side of pumps.	
2. Flexibility for routing flows and isolating equipment when needed.	
3. Avoid situations where sludge can get trapped between 2 closed valves.	
4. One quarter turn plug and bull valves are easy to operate and permit a degree of throttling control.	
5. Check valves should have an external arm to indicate valve position.	
D. Conveyors	
1. Transfer points	Slides 11-25 through 11-32: Sludge conveyor system.
a. Total enclosure of dump point and minimizing drop distance will reduce spashing.	Slide 11-27: Minimize drop distance to reduce splashing.
b. Rubber gaskets from hoppers to conveyor skirts and covered skirtboards will also reduce splashing.	

Lesson Outline	Illustrations/Key Points
2. Sludge Scraping a. Counted-weighted rubber bladed scrapers at head pulleys are not effective. b. Use of "finger" types scrapers is recommended. c. Shock absorbers will reduce blade bounce and keep them in contact with the conveyor belt. d. Scraper should be installed on flattened portion of belt to insure continuous contact.	
3. Belts a. Snubber pulleys, belt trippers, and gravity takeups require belt conveying sludge to turn-over a pulley and should be avoided. Use screw, cylinder or counted weighted take-ups. b. In the case of long lifts, 2 short belts should be used instead of one long one to avoid the need for gravity pickups. c. Catch basins, sumps or drainage are necessary at all dump points.	
4. Flexibility a. Most conveyors should be able to either receive or discharge sludge to two or more locations. b. Shuttle conveyors, rubber bladed belt plows, reversible conveyors and duplicate belt conveyors can aid in preventing conveying problems.	
5. Maintenance a. Provide work space around conveyor. b. Provide reversible belt with means of increasing tension. c. Provide water sprays for cleaning. d. Provisions for easy replacement of the belt should be made.	

UNIT PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES

UNIT 13

PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES - UNIT 13

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Design - Other Biological Processes

Instructional Goal: To develop in the student a wareness of operational considerations in the design of wastewater treatment facilities using other biological processes.

Method of Instruction: Lecture/Slides and Viewgraphs

Lesson Length: 1 hour

Instructional Resources

Student Manual print material
Viewgraphs of figures and tables
Slides
Unit Objectives

General Plan of Instruction

- Review the general operation of fixed film aerobic treatment and types of waste stabilization ponds.
- Show by examples operational features of trickle filters, rotating biological contactors (RBC) and waste stabilization ponds.

PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES - UNIT 13

OBJECTIVES

At the conclusion of this presentation, the participant should be able to:

- Define aerobic treatment.
- Describe well-designed trickling filters.
- List three advantages of trickling filters over activated sludge.
- List at least five "design hints" for trickling filters.
- Design underdrains for trickling filters.
- Identify ventilation needs for trickling filters.
- State at least four "design hints" for sludge production and handling in trickling filters.
- List four "design hints" for "cold weather" trickling filter.
- Describe operation of rotating biological contractors (RBC).
- List two RBC process alternatives.
- List at least four disadvantages of RBC's.
- Design RBC's for flexibility of operation.
- Discuss the design options available for stabilization ponds.
- List at least four "design hints" for stabilization ponds.

UNIT PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES - UNIT 13

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Instructors Presentation Guide

Unit of Instruction 13
Unit Process Design - Other Biological Processes

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Biological treatment of municipal wastewater primarily involves aerobiosis.	
B. The major divisions of aerobic treatment.	
1. Suspended growth - activated sludge and its modifications.	
2. Fixed film - trickling filters, RBC's.	Slide 1-39: Fixed film processes.
3. Wastewater stabilization ponds.	Slide 1-40: Classification of fixed film processes.
II. Trickling Filters	
A. Description	
1. Wastewater percolates over a bed of media covered with a bacterial slime which uses the soluble organic materials in the sewage for metabolism.	
2. Slime is continually sloughed off and is removed from effluent in a clarification basin.	
B. Advantages over activated sludge	
1. Easier to operate	
2. Lower energy requirements	
3. Smaller space requirements	
C. Disadvantages in relation to activated sludge	
1. Temperature sensitive.	
2. Less contact time between sewage and micro-organisms.	

Lesson Outline	Illustrations/Key Points
3. Head difference between influent and effluent end of filter is large and can require considerable energy to provide that head.	
D. Catagories	Table 13.1: Trickling filter process filter classifications and characteristics.
1. Low rate	
a. Remove 5 - 25 lb. BOD/1,000 $ft.^3$ of filter/day	
b. Hydraulic loading 25 - 100 $gpd/ft.^2$ of media.	
2. High rate	
a. 25 - 100 lb. BOD/1,000 $ft.^3$/day	
b. 100 - 1,000 gpd/ft^2	
3. Roughing rate	
a. More than 100 lb. $BOD/ft.^3$/ day	
b. 700 - 3,000 gpd/ft^2	
E. Design is based on empirical relationships developed by a number of different workers.	Table 13.2 - Trickling filter design formulas.
1. Almost all design formulas are based on first order biological kinetics.	
2. Series operation gives better effluent than parallel operation.	
F. Design Considerations	
1. Alternate lead filter in series operation to reduce clogging potential and maintain slime on both filters.	
2. Media	
a. Granite media, 3 to 5 inches in diameter has been traditionally used.	
b. Other media	
(1) Redwood slats	
(2) Plastic media (saddler and corrugated).	

Lesson Outline	Illustrations/Key Points
c. Advantages of manufactured media (1) Greater surface area/unit volume (2) Greater void space/unit volume (3) More uniform liquid distribution (4) Light weight which allows construction of deeper beds (5) Increased chemical resistance	
3. Wastewater distribution a. Rotary arms should be sized to prevent velocities greater than 4rpm b. Only 2 arms should carry flow during low flow periods. c. Design features that alleviate maintenance on distributor arms. (1) Adjustable tie rods (2) A dump gate on the end of each arm for flushing obstructions. (3) Means of spraying interior wall of filter to prevent buildup on filter walls. (4) A drain plug in the center of the distributor to facilitate shutdown and prevent freezing. d. Dosing (1) Provided by pumps, gravity discharge or dosing tanks. (2) Flow meters on dosing equipment will provide information on the amount of influent, recycle and permit equal distribution of flow among multiple filters. e. If distributor arms are rotated hydraulically, then recirculation can be used to keep them rotaing under low flow conditions.	

Lesson Outline	Illustrations/Key Points
4. Recirculation a. Low rate filters can be converted to high rate system. b. Used with synthetic media to maintain at least a 0.6 gpm/ft.^{2} wetting rate. c. Required for roughing rate systems to increase contact time and improve mass transfer	Table 13.3 - Advantages and Disadvantages of Recirculation on Trickling Filters.
5. Underdrains a. Design (1) Adequate capacity is necessary for rapidly discharging effluent and providing adequate ventilation. (2) No more than 50% of cross-sectional area should be submerged at peak flows (3) Ten states standards specify a 10% slope on underdrains and a minimum velocity of 2 fps (4) Outlet piping should be designed to insure that downstream obstructions will not prevent underdrains from working properly. (5) Provisions should be made for flushing underdrains and enabling inspection of the underdrains. b. Ventilation: Required to provide oxygen for aerobic decomposition of the soluble BOD. (1) Synthetic media often placed on columns allowing 2 or 3 foot opening around bottom for natural ventilation. (2) Forced ventilation (a) May be required if filters are below grade, if they are greater than 20 feet deep, if they are subjected to a heavy organic loading, or if covered filters are used.	

Lesson Outline	Illustrations/Key Points
(b) Normally designed for an air flow of 1.0 cfm/ft.^{2}, it should be adjustable to as low as 0.1 cfm/ft^2 for winter operation.	
6. Sludge Handling	
a. Final Clarifers	
(1) Low rate systems commonly designed with maximum overflow rates of 1,000 gpd/ft, while high rate sys-ems are designed at 800 gpd/ft.	
(2) Clarifier size can be optimized with a solids flux analysis on a similar trickling filter operation.	
b. Sludge production	
(1) Trickling filters typically yield 500 to 750 pounds of settleable solds per million gallons of wastewater.	
(2) Solids concentrate from 0.5 to 7.0 % in the final clarifier.	
(3) Sludge normally pumped to primary clarifier.	
(4) Intermittent solids removal using a positive displacement pump and timer allows maximum sludge con-centration.	
7. Provisions should be made for feeding chlorine to filter influent and polymers to filter effluent.	
a. Chlorine can control sloughing and odors.	
b. Polymers can be used for controlling dispersed growth that can occur from toxic industrial wastes or organic overloads.	
8. Ice formation considerations	
a. Two stage filters may be operated in	

Lesson Outline	Illustrations/Key Points
parallel in winter as the second stage in series operation is more subject to icing due to reduce influent temperature	
b. Adjustable orifices and splash plates on distributor arms will allow a thicker spray to prevent icing in winter.	
c. Dump gates at the ends of distributor arms can provide a stream to the outside filter wall to keep the wall from getting too cold.	
d. Winkbreaks will help prevent icing.	
III. Rotating Biological Contactors	
A. Introduction	Slide 5-201: Biosurf waste water treatment plant. Composed of 3 sets of 4 RBC's operated in serie Slow movement of wastewater simulates plug flow.
1. Process	
a. A fixed film process employing a series of closely spaced plastic discs on a rotaing shaft.	Slide 5-202: Schematic of the basic principle of RBC treatment.
b. The discs rotate through the influent wastewater and a layer of microbic slime on each disc utilizes the organic material in the waste for growth and metabolism.	
c. As slime builds up on the discs it is sheared off in the reservoir and wasted to a sedimentation basin.	
B. Media	Slides 5-203, 204, 205: RBC treatment facilities.
1. Constructed of high density polyethylene discs.	Slide 5-206: Corrugated media.
2. Corrugated, waffled or dimpled to obtain useful surface area ranging from 30 to 60 ft^2/ft^3 of media.	Slide 5-207: Dimpled media.
	Slide 5-208: Waffled media.
3. Media attached to a rectangular shaft either through a heat molded hub on the shaft ends or a structural steel spider dispersed throughout the shaft.	Slides 5-209 & 210: Media attached to rotating shafts.
C. Process Alternatives	Slide 5-211: Wastewater subjected to primary treatment, then moves to a series of 4 RBC/s separated baffles. The microbial solids are removed with the effluent and are settled out in a sedimentation basin.
1. Soluble BOD removal in secondary treatement.	

Lesson Outline	Illustrations/Key Points
2. Nitrification ordenitrification as a tertiary process.	
D. Advantages	Slide 5-212: Process configurations.
1. Energy requirements are lower than activated sludge (400 KWH/MGAL vs. 640 KWH/MGAL respectively).	Slide 5-213: Low energy requirements.
2. Maintenance costs are also low because shaft rotates at 1.5 RPM reducing wear.	Slide 5-214: Low speed, low maintenance.
3. Are easy to operate.	Slide 5-215: Ease of operation.
4. Cost competitive with both activated sludge and trickling filters over a 20 year life span.	Slide 5-216: RBC process modification: Sludge settles out beneath the RBC's, is settled and removed.
5. Operational factors	Slide 5-217: Covered RBC's.
a. Process stability since 95% of the microorganisms are attached to the discs and are not subject to washout.	Slide 5-218: Economical over 20 year life cycle.
b. No process decisions, such as sludge retention time or recycle rate to be computed.	Slide 5-219: Process stability.
c. Capable of handling shock loads.	
d. Little head loss through the treatment process, making RBC's good for plant upgrading.	
e. Microorganism/wastewater contact is intermediate between the trickling filter and activated sludge.	Slide 5-220: Mass transfer characteristics.
	Slide 5-221: RBC effluents.
f. MLSS is less concentrated than activated sludge and tends to settle in discrete particles. The sludge also does not have to be recycled reducing the flux on the final clarifier.	
E. Disadvantages	
1. Capital Intensive: higher front end costs than alternative forms of secondary treatment.	Slide 5-222: High capital cost.
	Slide 5-223: Poor response to transients.

Lesson Outline	Illustrations/Key Points
2. Poor response to transient loads.	
3. Media subject to stress cracking.	Slides 5-225 and 5-226: Media subject to stress cracking.
4. Lack of process control if an upset occurs.	Slide 5-229: No process control.
a. Few established techniques for controlling treatment under overloaded conditions.	
b. Sloughing and sludge age are uncontrolled.	
5. Disc organisms are sensitive to cold.	Slide 5-228: Sensitive to cold.
6. Poor aeration of wastewater has been observed.	Slide 5-224: Poor oxygen transfer
7. High rate of sludge production	Slide 5-227: High sludge production.
a. 0.1 to 0.2 lb. of sludge/lb. of soluble BOD_5 or 0.3 to 0.5 lb./ lb. of total BOD_5	
b. Little reduction of incoming solids.	
F. Comparison of activated sludge, trickling filters and RBC's.	Table 13.4: Comparison of Activated sludge, trickling filters and RBC's.
G. Design considerations.	
1. Design best accomplished using results of pilot plant studies especially for industrial applications.	Slide 5-232: Biosurf design criteria. See Figures 13.1, 13.2, and 13.3 Slides 5-241, 242, 243: Pilot plant operations. See Figures 13.4 and 13.5
2. RBC design data for secondary treatment.	Figure 13.4 Bio-surf process nitrification of domestic wastewater.
3. RBC design data for units run in nitrifying mode.	Figure 13.5 Hormel design curves for domestic nitrification Figure 13.6 Nitrate-nitrogen vs. ammonia nitrogen removal. Figure 13.7 effluent ammonia vs. Kjeldahl nitrogen.
H. Operational considerations	
1. Pretreatment of influent is necessary to prevent damage to discs. Pretreatment can be accomplished in primary sedimentation tanks, screens or grit chambers.	Slides 5-230,231: Hydrosieves use to remove potentially damaging particles.
2. Secondary clarifiers	
a. Use positive displacement pumps for sludge drawoff.	Figure 13.8: Recommended overflow rates.

Lesson Outline	Illustrations/Key Points
3. Design options for flexibility	
a. Air Drive	
(1) Can provide additional turbulence to aid removal of microbial slimes	
(2) Increase dissolved oxygen levels in wastewater reservoir.	
b. Enable rotational speed to vary between 1.0 and 2.0 RPM	Slide 5-247: Benefits of varying rotational speed.
c. If anaerobic conditons are anticipated in the influent, then preaeration step feed or hydrogen peroxide addition should be considered.	Slide 5-249: Step feed
d. Step Feed	
(1) If first stage loadings of greater than 5.0 lb/1,000 ft^2 are anticipated.	
(2) Will increase operating efficiencies during periods of treatment upset.	
(3) Can be achieved by separate piping or pulling bulkheads between stages.	
e. Transients loads tend to pass through the system untreated due to shorter detention time RBC than in activated.	Slide 5-250: Transient loads.
(1) Equalization will prevent the shock loads which reduce the ability of RBC's to treat transients.	
(2) Equalization will prevent excessive loss of biomass if toxic substances are contained in the influent.	Slide 5-251: Loss of biomass.
f. Sampling parts and provisions to feed chemicals should also be included in design.	Slides 252, 253: Sampling ports chemical feed.
(1) Treatment upsets can result in filamentous growth and dispersed growth carryover into the effluent olymers can be used to coagulate this dispersed growth.	

Lesson Outline	Illustrations/Key Points
IV. Stabilization Ponds	
A. Introduction	
1. An earthen basin of controlled shape and depth designed to treat wastewater.	Slide 5-1: Section through stabilization pond.
2. Popular in small communities because of low construction and operating costs.	
B. Classification	
1. Aerobic	Slide 1-41: Classification of stabilization ponds.
a. Shallow enough for sunlight to penetrate to bottom of pond.	Slide 5-2: Aerobic Ponds
b. Allows algae to proliferate throughout pond and release oxygen into entire pond volume.	Slide 5-3: View of aerobic pond.
2. Facultative Ponds	
a. 3 Layers	Slide 1-43: Section of facultative pond.
(1) Surface - Algae and bacteria	
(2) Middle - Facultative bacteria	
(3) Bottom - Anaerobic bacteria	
3. Anaerobic Ponds	
a. Are up to 20 feet deep	Slide 5-4: Anaerobic ponds.
b. Low surface area to volume ratios and high organic loadings.	
c. Stabilization is brought about by a combination of precipitation and anaerobiosis.	
C. Design of Stabilization Ponds	
1. Pond efficiencies are temperature dependent Flow strategies, storage capacities and intermittent or continuous discharge depend on climatic conditions.	Slide 1-44: Design of stabilization ponds.

Lesson Outline	Illustrations/Key Points
2. Should be rectangular to prevent short circuiting.	Slide 5-8: Square or rectangular ponds should be built.
3. Pond bottom must be relatively impermeable. Porous soils should be sealed.	Slide 5-9: Irregular pond: too flat side slopes, no maintenance along pond edges which allows debris to fall in.
4. There should be a freeboard of at least 2'.	Slide 5-10: Pond bottom relatively impermeable.
	Slide 5-11: A porous soil that should be sealed.
	Slide 5-12: There should be a freeboard of at least 2'.
	Slide 5-13: Poor berming. Side slopes too steep for maintennace.
	Slide 5-18: Levees: wide enough for maintenance vehicles, slope shallow enough for maintenance, rip rap or sodding to prevent erosion.
	Slide 5-19: Neither vegetation not rip rap to prevent erosion of berm. Note: Erosion line is evident.
	Slide 5-20: Poor rock levee. Rip rap just dumped and left.
	Slide 5-23: Banks should be planted with grass and regularly maintained to prevent bank deterioration.
	Slide 5-26: Animal burrow in pond bank. Can contribute to deterioration of banks.
5. Pond inlets	
a. Feed should be fast enough to assume self cleaning of distribution piping.	
b. Inlet piping should permit either parallel or series operation of ponds.	

Lesson Outline	Illustrations/Key Points
c. Inlets should be submerged and terminate over a concrete pad. (1) Center inlet for small ponds. (2) Inlet installed about 400' from dike for ponds of 10 acres or more. (3) For large ponds, multiple movable inlets are desirable.	Slide 5-14: Inlet structure submerged: promotes equality of influent distribution. Scour prevention: concrete pad under inlet port.
6. Pond outlets should provide control of pond depth and rate of discharge. a. Discharge pipe should be submerged. b. Should permit variable depth operation and effluent discharge from a desirable depth. c. Should be able to maintain different water level in each pond when operated in series. d. Provisions for complete draining of pond are desirable. e. Attach gauge stick to outlet structure.	Slide 5-15: Outlet structure Slide 5-16: Outlet control gate Slide 5-17: Unsubmerged outlet: allows little flow control and no variable pond depth operation. Slide 5-24: Emergent vegetation resulting from pond level dropping too slow. Slide 5-25: Emergent vegetation. Slide 5-21: Gauge stick and flow meter.
7. Pond sampling and flow monitoring a. Flow measuring of influent and effluent using a "V" notch or cippoletti weir and a float activated recorder. b. A microscope should be provided to help operator identify condition of the system. (1) Blue green algae or filamentous organisms can indicate low PH, DO or nutrient problems. (2) Protozoa can indicate low loadings or proper stabilization.	Slide 5-22: Level gauge in mid pond. Slide 5-27: Points of sampling and flow monitoring. See Figure 13.5 Slide 5-35: Flow chart Slide 5-28: Biological monitorin
8. Design for flexibility a. Enable series or parallel flow b. Each pond should have 3 distinct draw-off depths at the outlet structure.	Slide 5-30: Operational flexibility Slide 5-33: Series or parallel flow.

Lesson Outline	Illustrations/Key Points
c. Interpond transfer pipes will allow operator to redistribute pond volumes. Good operation requires capability of filling and drawing final cell to control algae and to permit discharge when operator chooses.	Slide 5-34: Variable drawoff Slide 5-39: Humorous ending

UNIT PROCESS DESIGN - OTHER FACTORS

UNIT 14

OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT
PLANT DESIGN - UNIT 14A

INSTRUCTOR LESSON PLAN

Unit Title: Safety

Instructional Goal: To make the student aware of necessary safety criteria and considerations in the design of wastewater treatment plants.

Method of Instruction: Lecture

Lesson Length: 1 hour

Instructional Resources:

Student Manual print materials
Unit Objectives

General Plan of Instruction:

- Discuss rationale for including safety features in wastewater treatment plant design
- Present sources for information concerning current laws and regulations
- Identify specific safety design considerations

SAFETY - UNIT 14A

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Justify the reasons for including basic safety necessities and requirements in designing or redesigning wastewater plants.
- Identify the kinds of personal safety considerations which should be considered in plant design.
- Identify available sources for information concerning current safety regulations and standards for plant design.
- Design/redesign wastewater plants which meet basic safety requirements and conditions and provide optimum safety for plant operators.

SAFETY - UNIT 14A

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(none)

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Instructors Presentation Guide

Unit of Instruction 14A
Safety

Lesson Outline	Illustration/Key Points
I. Introduction	
In the past the design of WWT plants has neglected safety.	The WWT Industry is one of the most hazardous. Failure to consider safety feature frequently requires immediate remodeling.
	Safety considerations should be fundamental to each stage of design.
The primary objective of this Unit is to encourage the Design Engineer to thoroughly research safety aspects in design.	This can best be done by consulting with operating presonnel.
II. Design Standards	
All recommendations are listed in the Water Pollution Control FEderation Manual of Practice #8 "Wastewater Treatment Plant Design."	Other sources are the National Safety Council and design considerations recommended by OSHA.
III. Design Standards	
A. General	
* Separate mechanical forced ventilation.	Areas requiring separate ventilation are influent room, wet wells, dry wells and screen or comminution rooms.
* Separation of facilities	Separate wet wells from other facilities.
* Pump stations	Stations should be equipped with super-structures to facilitate personnel entry.

Lesson Outline	Illustration/Key Points
* Forced ventilation systems	Systems should force air into wet wells to exclude sewer gases.
* Open Channel	Channels should be immediately ahead of influent structures to vent gases.
* Chlorination facility	Chlorine evaporator and storage rooms should be separate and located above ground.
* Automatic ventilation	Ventilation should be light switch activated in chlorination rooms, chemical handling rooms and laboratories.
* Ventilation exhaust	There should be no contamination of air inlets to other areas.
* Light and ventilating switches	Switches should be located outside of chlorination or chemical rooms.
* Special test areas	Ventilation with explosion proof motors should be provided in laboratory test areas and hoods.
* Hood and room exhaust systems	Care should be taken in design to preclude negative pressure within hoods.
* Storage Area	Separate storage for dangerous chemicals.
* Dust collectors	Effective methods for the removal of dust, ash and soot discharged from stacks should be provided.
* Incinerators	Provide facilities to preclude dust accumulation from dried sludge.
* Shop areas	Ventilation should be provided for permanent welding stations.

Lesson Outline	Illustration/Key Points
* Sludge storage tanks	Tanks should be located up stream of vacuum filters.
* Sludge pumps	Pumps should have pressure gauges to indicate the build up of gases when pumps are out of service.
* Gas protective devices	Devices should be incorporated into digesters in accordance with the manufacturers recommendations.
* Automatic gas alarms	Alarms should also be able to shut off all but emergency power.
* Chlorine leak detection systems	Systems should have "Fail Safe" features to shut off the flow of chlorine.
* Piping	Pipes to sludge pumps should be valved so that if the pumps are dismantled gases cannot enter the work area.
* Sampling valves	Pumps should have quick closing sampling valves.
* Wash down facilities	Facilities should be provided for sludge spillage.
* Corrosion preventatives	Piping and storage tanks should be coated to prevent corrosion.
* Emergency equipment	Pedal operated showers should be provided in all chemical handling areas.
* Hazardous areas	Portable ladders rather than man hole steps should be used to discourage easy entry.
* Incinerator controls	Automatic shutdown in the event of flame out should be provided.
* Disinfection systems	Systems should be selected to minimize handling.

Lesson Outline	Illustration/Key Points
* Corrosive liquid chemicals	Corrosive chemicals should have acid proof pumping equipment permanently installed.
* Gas outlets	Outlets should have substantial handles and be clearly identified.
* Dry hypochlorite	Cool, dry, well ventilated area should be provided.
* Chemical handling	Materials and devices should be compatible with the chemicals.
* Dikes and curbs	Contained area should be able to hold 125% of the chemical tank.
* Safety equipment	Safety equipment should include portable ventilation equipment, gas and oxygen deficiency indicators, vacuum cleaners, chlorine emergency kit, air breathing aparatus and protective clothing.
B. Facilities	
* Fencing	All facilities where unauthorized entry could result in mishap should be fenced.
* Laboratory equipment	Laboratory sinks should be pedal operated.
* Shower facilities	Facilities should be provided in the employee locker rooms.
* Food service	Cafeterias should be separated from all other facilities.
* Lockers	Two lockers for each employees should be provided.
* Washing machines	Machines should be provided for the washing of work clothes.
* Disinfectant dispensers	Dispensers should be located in shower and wash rooms.

Lesson Outline	Illustration/Key Points
* Potable water supply	System should be protected by back flow preventers.
* Non-potable water outlet	System should be color coded and have warning signs.
* Insect killers	Units should be considered for grit chambers and sand filter buildings.
* Bird repellers	Ultra-sonic repellent equipment is recommended if birds are a problem.
* Access doors	Doors leading to the outside should have panic hardware.
* Glazing material	Unbreakable glazing is recommended.
* Ground fault interruptors	Systems should be provided for power tools, lighting and test equipment outlets.
* Take up reels	Reels are recommended for welding cables, wash down hoses, airlines and power cords.
* Ramps	Ramps with non skid treads are preferrable to stairs.
* Door check	Systems should be installed on all critical doors to assure that they are closed.
C. Environmental	
* Personnel protection	Protection from infrared and ionizing radiation should be provided.
* Noise reduction	All equipment should be designed to achieve the most effective noise reduction possible.
* Lighting	Adequate lighting should be provided throughout the plant.

Lesson Outline	Illustration/Key Points
* Hand lift trucks	Trucks should be provided for chemical handling.
D. Physical Safety	
* Fire alarms and automatic fire fighting systems should be installed.	
* Laboratory walls and furnishings should be fire resistance.	
* Provide protectors at points of possible leakage if oxygen is used for activated sludge aerators.	
* Emergency power for critical lighting and ventilation should be available.	
E. Burns	
* Guards should be around hot exhaust piping.	
* Acid proof pumping for liquid chemicals should be permanently installed.	
F. Explosions	
* Entryway for rooms holding a gas or oil fired unit should satisfy safety requirements.	
* The wet well should have a separate structure or be accessible only from the outside.	
* Standby engines should be in separate structures.	
* Explosion proof electrical equipment should be provided wherever explosive gases may be present as a result of accident or malfunctions.	
* Electrical equipment associated with the wet well should be located in non-hazardous areas.	
* Safety equipment should include explosion proof flashlights and non-sparking tools.	

Lesson Outline	Illustrations/Key Points

* Safety harnesses should be available at vaults or pits.

* Digesters should have pressure relief valves.

* Traps should be installed at low points in the gas system.

* Waste gas burners should be easily observed.

* Gas collection systems should be segregated as much as possible.

G. Electric Shock

* All electrical wiring should be properly insulated, grounded and unexposed.

* Control circuit voltages should not be over 120 volts.

* All high voltage cables should be completely enclosed and adequately marked.

* Switch boards should have dead fronts and rears.

* Electrical "lock-out" facilities should be provided when equipment is being worked on or out of service.

* An emergency shutoff switch should be at all machinery units.

* Indoor control panels should be well ventilated.

H. Falls

* There should be rest landings on stairways.

* Stair risers should be of equal height and proper slope.

* Landings and stairs should have non-slip treads.

Lesson Outline	Illsutration/Key Points
* There should be a separate handrail for entrances to ship's ladders or manhole steps. * Floors should have non-slip surfaces. * In cold climates there should be gratings on outside stairs and on walkways around tanks. * Where spillage is a problem there should be sufficient faucets, adequate drainage and water repellent surfaces to aid cleanup. * Process tanks should have adequate railings, lifesaving devices and access ladders. * Lift rings should be flush-mounted to prevent tripping. * "Head Knockers" should be eliminated. * A safe method should be available for lamp replacement. * There should be emergency battery-operated lights for interior areas. * Proper painting will provide light color in dark areas and distinguish walking areas.	
I. Drowning * Manholes, steps or permanent ladders should be inside of tanks, basins or wet wells. * Life preservers with attached ropes should be available near open tanks. * There should be lifelines along internal walls.	
J. Impact * Equipment should be arranged for ease of access.	

Lesson Outline	Illustration Key/Points
* Passageway doors should be equipped with Lucite panels.	
* Stairways should have kick plates around openings.	
* Hatches should have springs or positive latches to hold them open.	
* Operations associated with railroad cars should be planned for safety.	
K. Rotating Machinery	
* There should be adequate space around machinery for maintenance.	
* There should be cages around exposed shafts and moving parts.	
* Shafts should have painted spirals to indicate running.	
* Positive displacement pumps should have an air chamber and a pressure switch to stop the pump at a pre-set pressure.	
* An emergency shutoff switch should be by all machinery units.	
* Running equipment should have indicator lights.	
L. Materials Handling	
* There should be hoists with ceiling devices for lifting heavy loads.	
* Hoists to lower and raise men and equipment into pit areas should be available.	
M. Warning Signs	
* Warning signs by each water outlet	
* One standardized color-coding of process piping and emergency equipment.	Standard colors are listed in the student manual.

Lesson Outline	Illustration/Key Points
IV. Personal Protective and Safety Equipment	
Even with the best design, unsafe conditions may be encountered.	The Design Engineer should specify the safety equipment and its proper location.
There are various categories of protective respiratory devices with specific applications and limitations	Respiratory devices are certified by NIOSH.

ENERGY CONSERVATION - UNIT 14B

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Apply design techniques to reduce electricity consumption.
- Reprogram electricity consumption to reduce peak load penalties.
- Specify pump systems to reduce energy consumption.
- Control air consumption in the activiated sludge process.
- Manage plant operation to control energy consumption.

ENERGY CONSERVATION - UNIT 14B

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Instructors Presentation Guide

Unit of Instruction 14B
Energy Conservation

Lesson Outline	Illustration/Key Points
I. Introduction	
In the past, in the design of WWT plants, energy conservation was not a major consideration of the Design Engineer.	Now all aspects of a WWT plant design are being analyzed for potential energy saving opportunities.
II. Energy Conservation Parameters	
A. Electricity Consumption	
1. Peak Demand	
* Utilities have different rates for different loads.	The WWT plant offers the Design Engineer many opportunities for reducing peak loads.
* Utilize the emergency generator for peak loads.	
* Provide influent surge capacity in order that overall plant load can remain more nearly constant.	
* Reschedule sludge processing operations.	
* After power failure, have an automatic sequencing system to limit peak re-starting loads.	
2. Power Factor	
The power load susceptible to penalty rates can be reduced by the following.	
* Operate motors at 50 percent to 125 percent of rated load where the power factor is high.	

Lesson Outline	Illustration/Key Points

* Utilize modern high-efficiency electric motors with high power factors.

* Install capacitors in parallel to correct the power factor.

3. Electric Motors

* High-efficiency motors may be more expensive but will pay for themselves by reduced consumption.

* Adjustable frequency source motors are more efficient.

4. Lighting

* Lighting can be zoned for two different illumination levels: one for safe access and a second for operation and maintenance.

* Sodium vapor lights can save 20 to 30 percent in electricity consumption.

B. Hydraulic Flow Regimes

1. Plant Operations

* Flow equalization by providing surge capacity can reduce peak power consumption by 20 to 30 percent.

* Adjust trickle filters to the actual operating conditions.

* Leave a portion of the RBC idle or operate at reduced speed during periods of low flow.

* Operate the sludge dewatering system intermittently so that will operate at peak efficiency.

2. Pumps

* Constant capacity pumps at design loads are most efficient.

Lesson Outline	Illustration/Key Points
* Centrifugal pumps can be efficiently controlled by throttling the suction.	
* Axial flow pumps cannot be efficiently throttled.	
* The output of positive displacement pumps can be efficiently varied by varying the speed.	
C. Air Consumption in Aeration Basins	
Activated sludge aeration basins are the major consumers of power at wastewater treatment plants.	Proper selection and operation of compressors and aeration basins can result in appreciable energy savings.
1. Air Compressors	
* Centrifugal compressors can be most efficiently controlled by throttling suction.	
* Positive displacement pumps can be controlled by speed or by multiple units.	
* Air pumps lend themselves to automatic control systems that match airflow to air needs.	
* The proper maintenance of air compressors is very important.	Dirty filters can increase the suction drop by up to 20 percent.
2. Aeration Basins	
The longer the solids retention time the greater the aeration energy consumption.	However, there is less sludge generation which might product offsetting energy savings.
D. Thermodynamic Budgets	
* Maximize sludge concentration going into the incerator.	At one plant one ton of sludge solids at 16 percent solids required 105 gallons of fuel oil while 25 percent only required 85 gallons.

Lesson Outline	Illustration/Key Points
* At the Corvallis, Oregon WWT Plant the heat of compression is used to heat the operations building.	
E. Utilization of Digester Gas	
A significant advantage in using anerobic digesters is that they produce methane.	An anerobic digester system can meet 75 percent of the power needed by an activated sludge WWT plant.
F. Management	
* Be aware of the availability of critical supplies.	Shortages may result in inefficient plant operation.
* Keep energy consumption records.	Changes in consumption rates can signal a malfunctioning system.
* The Design Engineer should design the plant to permit efficient operation during periods of energy shortages.	
* Chlorine residuals should be monitored to permit exact control of chlorine injection rates.	
III. Solar Energy	
Characteristics of WWT plants may lend themselves towards the utilization of solar energy.	
A. Low Temperature Processes	
Both activated sludge and anerobic digesters operate at temperatures below 100°F and thus are amendable to the use of single pane flat plate collectors.	
B. Acceptance of Diurnal Heating	
The thermal masses of aeration basins and clarifiers are great enough to effectively store daytime heating on into the night.	Anerobic digesters have a similar storage capacity.

Lesson Outline	Illustration/Key Points
C. Wilton, Maine Solar Heated WWT Plant	
A 450,000 gallon per day WWT plant has been built with an integral solar heating system.	
* The interior of the building is passively heated.	
* The RBC is heated by the Trombe wall.	
* A hydronic solar system is used to heat the anerobic digester.	The methane generated is not needed for heating and is thus available for electricity generation. It is easier to store the digester gas than heat.

OPERATIONAL CONSIDERATIONS IN WASTEWATER
TREATMENT PLANT DESIGN - UNIT 14C

INSTRUCTOR LESSON PLAN

Unit Title: Emergencies

Instructional Goal: To give the student a general overview of the types of standby equipment available and to acquaint the student with proper procedures to determine capacity.

Method of Instruction: Lecture

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Unit Objectives

General Plan of Instruction:

- Describe the different types of standby power sources available, focusing on the diesel engine powered generator system.
- Discuss procedures for the design; sizing and application of emergency power systems.
- Provide guidelines for the installation and maintenance of the diesel electric generator.

EMERGENCIES - UNIT 14C

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Identify the types of standby equipment available.
- Use proper procedures to determine capacity and type of equipment required for a given installation.
- Determine proper installation design and post-installation maintenance for a given system.

EMERGENCIES - UNIT 14C

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Instructors Presentation Guide

Unit of Instruction 14C
Emergencies

Lesson Outline	Illustrations/Key Points
I. Introduction	
Emergency electric power is required in WWT plants to:1) safely bring the plant to a shutdown condition and 2) maintain operation of the plant.	Batteries can provide power for the first condition but emergency generators are required for the second condition.
A. Power Outages	
The probable frequency and duration of power outages is a principal determinant in the selection of an emergency power system.	
* The primary causes of outages vary with service area.	Rural areas are more affected by weather while urban areas are more affected by equipment failures, overloads and vehicle accidents.
* The primary consideration in WWT plant design is the length of the outage rather than the frequency.	
* The possibility of outage or reduced voltage connected with national energy problems is real.	
* Laws, codes and regulations are not part of this presentation but they are major considerations in the selection of alternate power sources.	
* This presentation is limited to on-site generation.	However, it is possible to provide redundancy through two or more utility sources.

Lesson Outline	Illustrations/Key Points
B. Types of Emergency Systems	
When considering alternate power sources, dependability is the major consideration.	The most dependable alternate source of power is that generated on site.
* Standby emergency electric power system	It starts and assumes the load until the return of the normal power source.
* Supplementary standby (portable) system	It starts and assumes the load until the return of the normal power source.
* Peaking power system	It is used during periods of peak demand but is available in emergencies.
* Prime power system	The diesel generator is the normal source of power.
* Total energy systems	The diesel generator is the normal source of power, and heat and steam are recovered from the engine for other uses in the plant.
II. System Selection	
The selection of the component of an emergency generating system is dependent upon the system.	Having selected the type of emergency system it is then possible to specify the individual component of the system.
A. Number of Units	
Single unit diesel generators are the most economical and common. Multiple units are sized to carry separate portions of the emergency load. Parallel units are used when the load is too great for single unit or where redundancy is desired in the emergency system.	

Lesson Outline	Illustrations/Key Points
B. Capacity	
The electric plant must provide enough capacity to serve the load it will be expected to carry.	The load may be the total KW load but it is often less because all units may not be operating at one time.
* Starting motors draw more power than their maximum running load.	In addition to total motor horsepower the sequence of operations must be considered.
* In order to properly size a diesel generator many facets must be considered.	The Students Manual list some of these facets on Page 14c.5
* It is often tempting to specify excess capacity.	However, running a diesel engine at reduced load can be harmful.
* It is normally not necessary to specify engine horsepower.	The manufacturer will provide the appropriate engine for the specified KW load.
* The generator must have capacity to serve the peak KW load at the load power factor where large motors are started across the line.	The primary method of reducing the required generator capacity in a high motor load application is by sequencing motor starting.
C. Rating	
Generators are available to match the exact requirements of an application.	
* An electric generator set must have enough capacity to serve the peak load and adequate power margin to recover frequency after load changes.	There are two basic unit ratings in use: The continuous rating and the standby rating.
* An alternator operates at a single synchronous speed.	The rated capacity of a generator is stated on the nameplate in terms of KW, KVA, voltage, power factor and temperature.

Lesson Outline	Illustrations/Key Points
D. Voltage Regulators	
Most voltage regulators in use today are the solid state type without any mechanical contacts.	The table on Page 14c7 of the Student Manual shows typical voltage regulation characteristics of a diesel electric generator set.
E. Frequency Control	
To produce alternating current at a specified frequency, the engine must drive the alternator at a corresponding synchronous speed.	The hydraulic governor is the most common in use today and can provide frequency regulation in a range of 2 percent to totally isochronous.
F. Starting System	
To start a diesel engine, it must be cranked until compression ignition has been achieved and the engine is running on its own.	The electric starting systems is by far the most common in use today and consists of a dc electric motor starter, batteries and a battery charging system.
G. Starting Controls	
Since most standby units must start and operate automatically, a system of controls must be provided.	Normal meters in a control panel are a voltmeter, ammeter frequency meter and a running time meter.
* The start/stop controls automatically starts the emergency generator on a signal from a remote switch, and stops the emergency generator when normal power has returned.	
* An automatic transfer switch is designed to automatically connect the load to either of the two power sources.	A power failure monitor recognizes a power failure and initiates the engine start and transfer command.

Lesson Outline	Illustrations/Key Points
H. Noise Muffling System	
Noise level must be limited in many applications to meet EPA and OSHA regulations.	In most cases, it is best to specify the sound pressure level reading desired and require that the manufacturer and installer of the standby system meet this level.
III. Installation	
A. Location	
* The inside installation is the most complex.	Factors to be considered include cooling and combustion air flow, noise, vibration, exhaust system routing and available floor space.
* The housed unit for a self contained diesel generator is becoming more widely used.	This is due to the ease of installation, package responsibility and lower space cost.
* Trailer mounted units are used where two or more loads may be served by a single generator and portability is desirable or required.	
B. Foundation	
A properly engineered electric plant will be shipped assembled on a rigid base and needs merely to be set in place on vibration isolation pads and leveled.	
C. Ventilation	
Any internal combustion engine requires liberal ventillation for cooling and combustion.	Several factors must be considered: electric plant heat rejection to the atmosphere, air required for cooling and air required for combustion.

Lesson Outline	Illustration/Key Points
D. Exhaust	
Engine exhaust must be directed to the outside through a properly designed exhaust system that does not create excessive back pressure.	To reduce the noise from the pulsating exhaust, a proper silencer is required.
E. Cooling	
A diesel engine is cooled by circulating a liquid coolant through the air cooler and through passages in the engine block and head.	The coolant is cooled in a radiator with either an engine or electric motor driven fan.
F. Fuel System	
A dependable fuel supply system must assure instant availability of fuel to facilitate starting and to keep the engine operating during an emergency.	A storage tank is the major component of the fuel system. A day tank is normally required since engine driven pumps have minimal lift capability.
IV. Maintenance	
A. Procedures	
Maintenance procedures should be an integral part of the Operations Manual prepared by the Design Engineer.	Experience shows that 90 percent of all past equipment malfunctions can be attributed to improper maintenance.
B. Inspections	
Operating tests should be conducted on a weekly basis.	This should always be conducted under load and should be of at least 30 minutes duration.
C. Service	
Most distributors of emergency power systems can offer maintenance contracts or agreements.	

UNIT PROCESS SELECTION - A SYSTEMS APPROACH

UNIT 15

OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT PLANT DESIGN
UNIT 15

INSTRUCTOR LESSON PLAN

Unit Title: Unit Process Selection - A Systems Appraoch

Instructional Goal: To develop in the student an awareness of the methodologies for a systems approach to the unit process selection.

Method of Instruction: Lecture

Lesson Length: 2 hours

Instructional Resources:

Student Manual print material
Familiarity and experience of the instructor with the "Executive Digital Computer Program for Preliminary Design of Wastewater Systems."
Unit Objectives

General Plan of Instruction:

- Introduce the need and advantages of a systems design approach to unit process selection.
- Review system aspects of the "Executive Digital Computer Program For Preliminary Design of Wastewater Treatment Systems"

UNIT PROCESS SELECTION - A SYSTEMS APPROACH - UNIT 15

OBJECTIVES

At the conclusion of this presentation the participant should be able to:

- Describe the steps to be accomplished in performing a system design.
- State the need for a system design approach.
- List the advantages of a system design concept.
- Describe the methodology and demonstrate the application of the system design concept.
- Recognize and utilize the Abridged User's Guide.

UNIT PROCESS SELECTION-A SYSTEMS APPROACH
UNIT 15

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Instructors Presentation Guide

Unit of Instruction 15:
UNIT PROCESS SELECTION - A SYSTEMS APPROACH DESIGN CONCEPT

Lesson Outline	Illustrations/Key Points
I. Introduction	
A. Project is designed as a whole in "systems design" approach.	
B. Steps in a "system design".	
1. Define objective of project.	
2. Identify project constraints.	
a. Complex interrelationships exist.	
(1) Air Pollution requirements	
(2) Facility siting	
(3) Time constraints	
(4) Municipality viability	
(5) Political climate	
(6) Attitude of decision making	
3. Establish specific project criteria for the whole and its individual components.	
a. Economic factors	
b. Design flexibility	
c. Seasonal and short term variations	
d. Project reliability	
e. New design versus rehabilitation	
f. Process engineering parameters	
4. Formulate acceptable design alternatives.	

Lesson Outline	Illustrations/Key Points
5. Evaluate effect of design alternatives. a. Overall efficiency of alternatives b. Direct and indirect cost of alternatives c. Environmental effects d. Energy requirements e. Effect of various components on plant utilities 6. Select the best alternative. a. Value placed on consequences of each trade-off allows decision-makers to make valid comparisons. II. Need for System Design Approach A. Must consider entire process train in design approach in order to anticipate consequences. B. Can assess, in advance, the interaction of the operator with the facility. C. Can identify potential difficulties in operation and maintenance before start-up. D. Can devise operations manuals and training programs based on perceived needs. III. Advantages of a System Design Concept A. Allows identification and alleviation of design problems before they are incorporated in a facility. B. Design, construction, and operations start-up teams will be better able to trouble-shoot start-up and operational problems. C. Allow evaluation of process interactions. D. Provides design with a thorough evaluation of performance, impact, and costs of the selected design alternative.	

Lesson Outline	Illustrations/Key Points
IV. Methodology and Application of the System Design Concept A. Mathematical computer model can minimize computation of work required to examine alternate designs. B. Models could be steady state, quasi-steady state, or time-dependent. 1. Quasi-steady state uses a steady state model to describe non-steady state processes. 2. Time dependent models are useful when effluent quality varies with time or when control scheme effectiveness is being investigated. C. Effective models have the following characteristics: 1) Based on valid scientific principles, 2) Has flexibility to simulate experimental data from a full-scale process, and 3) Can represent the performance and cost of the process with adequate precision. D. Valid, complete experimental data must be used to "tone" the model. E. Computer models packaged as computer programs provide easy access to the using audience. F. EPA has developed the Executive Digital Computer Program for Preliminary Design of Wastewater Treatment System. 1. Simulates groups of conventional and advanced wastewater treatment unit process arranged in any logical manner. a. Select unit processes b. Arrange processes into desired configuration c. Calculate system performance d. Calculate system cost	

Lesson OUtline	Illustrations/Key Points
2. Additional process models can be added to the program as developed.	
V. Abridge User's Guide	
A. Instructor familiar with the "Executive Program: should discuss the User's Guide.	

EQUIPMENT SELECTION AND PLACEMENT FOR OPERABILITY FLEXIBILITY AND MAINTAINABILITY

UNIT 16

OPERATIONAL CONSIDERATIONS IN WASTEWATER
TREATMENT PLANT DESIGN - UNIT 16

INSTRUCTOR LESSON PLAN

Unit Title: Equipment Selection and Placement for Operability, Flexibility and Maintainability.

Instructional Goal: To familiarize the student with techniques to properly select and place items of equipment and acquaint them with the opportunities in utilizing computers in wastewater treatment plant design.

Method of Instruction: Lecture

Lesson Length: 1 hour

Instructional Resources:

Student Manual print material
Unit Objectives

General Plan of Instruction:

- Describe criticality analysis, selection considerations and information sources for the selection of equipment.
- Discuss proper techniques for placing equipment for operability, flexibility and maintainability.
- Suggest some of the possibilities of advanced computer design techniques.

EQUIPMENT SELECTION AND PLACEMENT FOR OPERABILITY,
FLEXIBILITY AND MAINTAINABILITY - UNIT 16

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Describe the often overlooked consequences of inadequate consideration of operations and maintenance in the selection and placement of equipment.
- Discuss criteria to best achieve the designed function of the equipment to the maximum extent possible in a cost effective manner through proper selection and placement.
- Identify sources of information for new equipment.
- Apply evaluation methods to the performance of new equipment.

EQUIPMENT SELECTION AND PLACEMENT FOR OPERABILITY FLEXIBILITY AND MAINTAINABILITY - UNIT 16

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Instructors Presentation Guide

UNIT OF INSTRUCTION 16

EQUIPMENT SELECTION AND PLACEMENT
FOR OPERABILITY, FLEXIBILITY AND MAINTAINABILITY

Lesson Outline	Illustrations/Key Points
I. Introduction	
A large percentage of recently constructed WWT Plants are not achieving design efficiency.	An important contributor to these deficiencies are failures in the selection and placement of equipment based upon operation, flexibility and maintainability
II. Selection of Equipment	
A. Criticality Analysis	
Determine how the mechanical components in the WWT Plants would have an impact on final effluent quality if they failed.	Criticality analysis would entail the following activities.
* Classify the principal unit operation of the WWT plant.	
* Critically evaluate the unit operation as to its failure upon effluent quality.	Also analyze the time factor between failure and impact on effluent quality.
* Similarily evaluate individual equipment items.	
* Evaluate alternative actions.	The adaption of alternative actions can make the selection less critical.
* The normal equipment selection may then proceed.	

Lesson Outline	Illustrations/Key Points
B. Equipment Selection Considerations	
* It is no longer satisfactory to only specify the general type of equipment.	
* Secondary function of the piece of equipment should be considered.	
* The "true efficiency" of a piece of of equipment should be considered.	Servicing and maintenance efficiency should also be considered.
* The manufacturers servicing history should also be considered.	
* For plant expansions, present equipment should be evaluated.	Operation and maintenance efficiency can be improved if similar equipment is used.
* Local capabilities for operation and maintenance should be considered in the selection of equipment.	Poor operation is frequently due to over sophistification.
* The "true cost" not just the capital cost should be considered.	Service and maintenance cost should also be considered.
* Consideration of proven equipment must be included in the selection process.	
C. Equipment Information Sources	
* Manufacturer's Representatives	He is a good source of information but the designer is responsible for the selection.
* Equipment Shows	Exhibitors usual have knowledgeable personnel to explain and discuss the equipment.
* Professional Journals	Information may be obtained in advertisements as well as articles.

Lesson Outline	Illustrations/Key Points
* Visit new treatment facilities	It gives insight and ideas to see different design approaches.
D. Equipment Performance and Evaluation	
* Manufacturer's field test data	Usually the manufacturer has field tested the equipment prior to production.
* Pilot Studies	If possible observe the studies.
* Inservice reliability analyses	Operation and maintenance data is used to estimate failure rates, meantime between failures, mean time to repair and availability for WWT plants.
III. Placement of Equipment	
A. Operability	
* Equipment must be placed in accordance with the manufacturer's recommendation.	
* Placement of controls is as critical as the placement of the equipment.	Controls must be located for accessibility and control.
* The designer should locate inter-dependent functions near each other.	
B. Flexibility	
* The designer must consider the possibility of future expansion without a total shut-down of the system.	
* Location of the equipment is normally considered for the primary function.	Secondary functions that can be efficiently effected should be considered.
C. Maintainability	
* The most neglected criteria for equipment placement is the area for repairs and maintenance.	
* Every item of equipment can fail.	Consideration must be given to servicing the equipment.

Lesson Outline	Illustrations/Key Points
IV. Computer Design for Operability, Flexibility and Maintainability.	
WWT plants are frequently poorly designed due to the inherent limitations of blueprints and plans.	They are the two dimensional vehicle to describe a three dimensional world.
Advanced real time computer program with interactive video displays are available.	The designer can "see" a three-dimensional view of the design from any angle and can spot and correct space conflicts.

AN OPERATOR SPEAKS TO THE DESIGN ENGINEER

UNIT 17

OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT
PLANT DESIGN - UNIT 17

INSTRUCTOR LESSON PLAN

Unit Title: An Operator Speaks to the Design Engineer

Instructional Goal: This Unit, unlike the other units, is not pre-structured with a unit goal. The Instructor of this unit should feel free to discuss with the participants those subjects that he, based upon his experience, believes to be pertinent to the overall course goals. It is suggested, however, that the relationship between the Operator and Design Engineer be one of the unit goals.

Method of Instruction: Lecture and such other methods as the instructor elects.

Lesson Length: 2 1/2 hours

Instructional Resources: The Instructor of this unit should have extensive operating experience and familiarity with aspects of the design, construction and start up of wastewater treatment plants. This unit can be structured around a visit to a wastewater treatment plant, the personal visual aids of the Instructor, or on course material prepared for the presentation.

General Plan of Instruction: To be determined by the Instructor.

AN OPERATOR SPEAKS TO THE DESIGN ENGINEER - UNIT 17

OBJECTIVES

This Unit, unlike the other units, is not prestructured with a course syllabus and visual aids. The Instructor of this unit will be free to discuss with the participants those subjects that he, based upon his experience, believes to be pertinent to the overall course objective. It is suggested, however, that the relationship between the Operator and the Design Engineer be one of the topics discussed. Thus, at the conclusion of the presentation the participant shall be able to describe the relationship between the Operator and the Design Engineer.

AN OPERATOR SPEAKS TO THE DESIGN ENGINEER - UNIT 17

INDEX TO VISUAL AIDS

Figure/Slide

(as determined by the Instructor)

Table

(as determined by the Instructor)